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Quantifying Institutional Impacts and Development Synergies in Water Resource Programs:

A Methodology with Application to the Kala Oya Basin, Sri Lanka

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Abstract

The success of development programs, including water resource projects, depends on two key factors: the role of underlying institutions and the impact synergies from other closely related programs. Existing methodologies have limitations in accounting for these critical factors. This paper fills this gap by developing a methodology, which quantifies both the roles that institutions play in impact generation and the extent of impact synergies that flows from closely related programs within a unified framework. The methodology is applied to the Kala Oya Basin in Sri Lanka in order to evaluate the impacts of three water-related programs and the roles of 11 institutions in the context of food security. The results provide considerable insights on the relative role of institutions and the flow of development synergies both within and across different impact pathways. The methodology can also be used to locate slack in impact chains and identify policy options to enhance the impact flows.

This paper—a product of the Sustainable Rural and Urban Development Team, Development Research Group—is part of a larger effort in the department to mainstream research in water resource economics. Policy Research Working Papers are also posted on the Web at http://econ.worldbank.org. The authors may be contacted at r.saleth@cgiar.org and adinar@worldbank.org.

QUANTIFYING INSTITUTIONAL IMPACTS AND DEVELOPMENT SYNERGIES IN WATER RESOURCE PROGRAMS: A Methodology with Application to the Kala Oya Basin, Sri Lanka*

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Keywords: *Development Programs, Econometric Analysis, Food Security, Impact Pathways, Impact Synergy, Institutional Analysis, Institution-Impact Matrix, Kala Oya Basin, Millennium Development Goals, Perception Data, Sri Lanka, Stakeholder Evaluation.*

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CONTENTS

SUMMARY

With increasing investments in development programs in general and water-related programs in particular, there are obvious concerns regarding their actual impacts on development objectives. Two persistent aspects hamper their proper evaluation both in economic literature and in development policy: (a) the specific roles that institutions play in the process of impact generation and transmission, and (b) the impact synergies that a development program derives from past, ongoing, and planned programs. Exclusion of these aspects is very important, particularly in the evaluation of *meta* development goals such as food security, where the realization of the final objective is linked with the progress of several intermediate but related targets of a hierarchy of programs spanning across sectors and time.

This paper develops and applies a methodology that explicitly captures the effects of both institutional roles and development synergies within a unified framework and quantitative context. The development of the framework is illustrated by (a) referring to a set water and agriculture-related development programs (system rehabilitation, bulk water delivery, and crop diversification), (b) tracing their impact pathways and interaction points, (c) locating relevant institutions in these points and pathways, and (d) linking them all with the final goal of food security—one of the key targets of the Millennium Development Goals. This framework is, then, translated into a system model with 21 sequentially linked equations, comprised of a set of development, institutional, and impact variables. For the practical application of the framework, the Kala Oya Basin in Sri Lanka is taken as the empirical context and the perception-based information collected from a sample of 67 experts is used as the data source.

The estimation of the model coefficients provides considerable insights on the nature of both the roles that different institutions play at various points of the impact pathways as well as the synergies that development programs derive from each other. The sensitivity analysis performed with the reduced form equation suggests that, in terms of the marginal effects on food security, market institution has the highest effect, followed by others such as price regulation and trade policy. Unlike these institutions with a positive effect, there are others with a negative contribution such as land tenure and rural development policy.

From the perspective of practical policy, this paper has two main contributions. First, it demonstrates the importance of accounting for the institutional impacts and development synergies when planning and implementing any new development program in a given region. Second, it provides a diagnostic tool both for locating the weak spots and slack links in various impact pathways of a development program by identifying the institutions and impact chains that are to be strengthened to improve the impact flows of development programs.

1. MOTIVATION AND CONTEXT

The motivation for this paper comes from two major gaps persisting in the theory and practice related to the critical subjects of development impact and institutional analysis. First, there is a lack of proper treatment of the synergies inherent among development programs, projects or policies with common or closely related goals.[1] These synergies occur not just among ongoing programs but even flow from those completed in the past and planned for the future. The evaluation of the impacts of development programs cannot be complete without accounting for these synergies. These synergies are particularly important for composite or *meta* development goals (e.g., Millennium Development Goals,[2] combating climatic change, and governance reforms). This is because the realization of these goals is critically linked with the realization of several intermediate but related goals of a hierarchy of development programs. Second, institutions, defined as a system of legal, policy, and organizational components (Bromley, 1989; Ostrom, 1990), play a central role both in the facilitation and transmission of development impact. Although the general roles of individual institutions are being evaluated in various contexts and details (Saleth and Dinar, 2004 and 2008), there is an insufficient attention on the individual and joint roles several institutions in the specific context of impact generation and transmission. These two gaps are obviously serious in view of the bias and gaps they could cause in the planning, implementation, and assessment of development programs.

Ironically, the issue of the lack of or insufficient treatment of impact synergies and the institutional roles in development impact is not entirely new as are its consequences to impact assessment, institutional analysis, and development planning. But, the problem persist essentially due to the absence of an empirically applicable methodological framework that can bring together the multiple impact pathways of two or more development programs within a common analytical framework and single evaluation context. These pathways are very important as they capture the various routes through which the impacts of a program are transmitted on to the final goal and these routes can be characterized by a chain of sequentially and functionally related development, institutional, and impact variables.[3] Existing impact assessment approaches are of no or little help in this context due to their inherent analytical limitations.[4] Since they do not elaborate the impact process to capture the entire set of impact pathways, they miss the opportunity to locate and evaluate the impact role of institutions in the specific contexts of different pathways. With their *ex-post* orientation and reliance on objective data, the existing approaches also become unsuitable particularly in the context of multiple and time-lagged projects with continuing, lagged, and uncertain flow of impacts. Here, *ex-ante* approach and subjective information are unavoidable.

This paper aims to develop and empirically illustrate a methodology that can directly capture both the development synergies and the institutional roles within a unified framework and quantitative context. The methodology is based on an analytical framework that traces the major impact pathways between the development programs and the development goal and characterizes these pathways in terms of the sequential and functional linkages among the development, institutional, and impact variables involved. Since these linkages can be translated into a system of structurally linked equations, each capturing different impact pathways, the framework can be mathematically translated for empirical application and quantitative evaluation. This paper demonstrates the application of this methodology in the empirical context of the Kala Oya Basin in Sri Lanka by taking (a) the food security related to the first MDG as the development goal, (b) a set of three water-related programs—namely, system rehabilitation, bulk water delivery, and crop diversification—as the candidate development programs,[5] and (c) the ex-ante information from a sample of 67 stakeholders—consisting largely of government officials and national experts—as the data source.

From here, the paper is structured as follows. Section 2 provides a graphical illustration of the welfare implications of both the development synergies and institutional role and indicates the policy value of their *ex-ante* evaluation. Section 3 sets the analytical framework with the conceptual foundation and building blocks of the proposed methodology. It also presents an institution-impact matrix developed in a generic context that can serve as a platform to operationalize the conceptual model into an empirically applicable form. Section 4 describes the study area and highlights its major development challenges. Section 5 applies the institution-impact matrix to the development and institutional context of the study region. It provides both a graphical presentation of the impact pathways in terms of a flow diagram and a mathematical representation of these pathways as a set of functional relationships evident among development, institutional, and impact variables. Section 6 describes the data source and also provides empirical precedence and theoretical justification for using stakeholder-based *ex-ante* information. Section 7 presents and analyzes the results of the econometric models of institution-impact interaction. It provides statistical evidence for the relative role and significance of the development, institutional, and impact variables in difference equations representing various impact layers and also demonstrates the structural linkages among these equations or layers of impact pathways. Section 8 provides numerical evidence for the size and flow of development synergies and institutional impacts based on a sensitivity analysis of the reduced form equation in terms of the local and system-wide impacts of a marginal change in different variables. The final section concludes with the analytical and empirical insights of the paper, its limitations, and the scope for its future extension and refinement.

2. Impact Synergies and Institutional Roles: An Illustration

When selecting development programs, policy makers usually make an *ex-ante* assessment of their effects both on overall welfare and on its distribution across groups in the society. But, such assessments often ignore the issue of how this welfare and its distribution would change when the roles of institutional impacts and synergies from related programs are taken into account. The practical importance and policy value of considering these changes in such an *ex-ante* assessment is graphically demonstrated using Figure 1, which is an adaptation of a framework suggested by Just et al. (2004).

Figure 1 depicts a simple economy with two individuals (or groups), i.e., *I* (rich) and *J* (poor), who, with a given bundle of resources, can produce/consume two goods, i.e., food (*F*) and recreation (*R*). Given current technologies and institutions, the production possibility frontier for the economy is OP. Assume that the economy is in a status quo at $(i,j)^0$ with a corresponding welfare levels for the two-person society. Based on the Edgeworth Box analysis, J's welfare is: JF(0)+JR(0) and I's welfare is [P-JF(0)]+[O-JR(0)]. Now, suppose the government wants to take the economy towards the frontier OP and improve, thereby, both the total welfare and its distribution. For this, it considers two programs, which are expected, *a priori*, to achieve such economic and social objectives, i.e., a 'dashed' (dashed line) program (D) and a 'solid' (solid line) program (S). As can be seen from Figure 1, the 'dashed' program moves the economy from $(i,j)^0$ to $(i,j)^D$ and the 'solid' program moves the economy to $(i,j)^S$. Both policies are Pareto optimal in the sense that they satisfy the condition of utility maximization for both individuals/groups. But, the 'dashed' program is less efficient as it falls short of the production possibilities frontier (OP) and ends with an inner frontier, O'P'<OP. However, from a political economy perspective, the 'dashed' program can be the second best option and it may very well be the final choice of the policy maker. This is because I (rich) is less likely to oppose this program with a lower loss in allocation as compared to the 'solid' program.

In the discussion so far, the focus is only on the welfare and distribution implications of two alternative programs. In this case, an *ex-ante* assessment of the development path and its economic implications is usually conducted with actual and expected information before the policy choice is made. But, such assessments do not account for the economic externalities from institutional facilitations and impact synergies from related programs. Using Figure 1, we can demonstrate how the additional welfare gains are missed when impact synergies and institutional roles are ignored. Let us assume that the economy is, again, in status quo at $(i,j)^0$. Suppose that a development program, say, an irrigation project, is implemented, leading to a development path represented by the dashed line. Now, the economy attains a new equilibrium at $(i,j)^D$ on the production frontier O'P'. Clearly, the new equilibrium, though increasing the welfare with more food and recreation, falls short of the optimum. Suppose, there is another development program, say, crop intensification that is also implemented either along with or subsequent to the irrigation project. Since crop intensification enhances the welfare impacts of the irrigation-based program, the latter can get considerable development synergies from the former program. When these impact synergies are taken into account, the economy will reach a different production frontier and development path with a new equilibrium, say, at $(i, j)^S$. This new equilibrium, which accounts for the impact synergies, generates higher and still equitable allocation of food and recreation.

In a similar vein, we can also demonstrate the welfare gains from incorporating the role of institutions. Suppose that the irrigation-based development program is implemented in conjunction with the introduction of a water allocation institution (e.g., rotational water supply or volumetric water allocation). In this case, the production possibility frontier will shift outward and the development path will also change from the dashed line. To minimize notations and complications, let us consider that the new production frontier is OP and the development path is the solid line. With this, the equilibrium will move from $(i, j)^D$ to $(i, j)^S$. The difference between the two equilibriums shows the welfare gain of considering the role of institutions in development process. We can note here that in the context of impact synergies between development programs, although the economy is actually at a higher welfare level, project-based impact assessments are not able to fully account for them. But, the problem is still more serious in the context of institutional effects because the roles of institutions are not incorporated with proper detail in development planning itself, let alone the actual assessment of their impact.

3. The Methodological Framework

The reality of impact synergies associated with multiple programs and the intricate roles that institutions play in enhancing and channeling these synergies obviously requires a major change in the way development impacts are assessed. In particular, what is needed is an analytical framework that is capable of capturing both the individual and collective impacts of development programs as well as the intrinsic roles of institutions within the impact generation and transmission process. We also need an evaluation methodology that can bring together the impacts of multiple programs and the roles of institutions within a common analytical framework. Clearly, this is a major challenge because the required methodology has to be generic enough to transcend disciplinary boundaries and empirical limitations. But, as we will argue below, it is possible to construct such a generic methodology by selectively combining useful elements from the methodologies, which are used both in the impact assessment and institutional analysis literatures.

3.1. Conceptual Setting

The conceptual setting for the generic methodology is presented in Figure 2. This setting suggests indeed the basic conception of a model of institution-impact interactions in the context of a given region. Specifically, there are three sets of interactions, i.e., among development programs (capturing impact synergy), among institutions (capturing institutional linkages), and among the programs, institutions, and food security (capturing together the development and institutional impacts on food security). The required methodology has to be broad enough to simultaneously handle all these interactions. As will be argued below, such a methodology can be developed by combining suitably adapted analytical and methodological elements from the impact assessment and institutional economics literatures. Specifically, some of the existing impact assessment methods can be used to handle the impacts of and interactions among development programs whereas some of the institutional analysis methods can be used to capture the mediating roles and development impacts of institutions.

3.2. Building Blocks of the Methodology

Despite their analytical and empirical limitations, some of the impact assessment methods do have useful elements for building a generic methodology for evaluating multiple and time-lagged programs. One of them is the Method for Impact Assessment of Programmes and Projects (MAPP).[6] Although MAPP allows an integrated evaluation of multiple programs with stakeholder-based information, it has few major but avoidable analytical and empirical limitations. First, it is not capturing all impact pathways and channels operating between the programs and their final goals. Second, the important roles of institutional factors, especially their interactions with other development and impact factors are not incorporated. In fact, this problem emerges directly from the first limitation because the institutional roles cannot be evaluated without considering the impact pathways in the first place. Finally but more importantly, the point-based evaluation used in this method allows only a qualitative but not a quantitative analysis. This is because the points awarded by stakeholders are not on metric scale with an absolute point to serve as benchmark. While the first two problems can be rectified with suitable extensions and adjustments of MAPP, the last one can be solved with few intermediate steps for making the point system relative and comparable (see Neubert, 2006).

Another method that has useful inputs for the present purpose is the Poverty and Social Impact Assessment (PSIA) method.[7] Despite its focus on single program, PSIA not only focuses on few specific impact pathways but also allows the use of perceptional data and ex-ante analysis (see Coudouel, Dani, and Paternostro, 2006:12). This method with few adjustments can provide some key elements for building a more generic and robust methodology. First, the number of impact pathways has to be increased to consider major, if not all possible, impact pathways. This is essential to enrich the analytical framework so that it can capture both the development synergies and institutional impacts, which are captured and channeled through various impact pathways. Second, even though the PSIA recognizes the exogenous influence of institutional factors, it is necessary to explicitly incorporate them as part of the evaluation framework itself and also analytically capture their interactions with other development and impact variables characterizing different impact pathways. Third, the use of *ex-ante* approach and stakeholder information, though important to deal with the impact expectation and uncertainty, still may lead to a serious bias as long as the evaluation is performed by the direct beneficiaries (Coudouel, Dani, and Paternostro, 2006:11). This is an important empirical point, which strongly suggests the need to select neutral stakeholders or a more balanced group of respondents.[8]

Besides the selective adaptation and use of relevant analytical and empirical elements from the impact assessment literature, we also need similar elements from the institutional economics literature, mainly for capturing the institutional dimension of the required methodology. In this respect, the theoretical framework developed by Saleth and Dinar (2004) is particularly useful for explicitly accounting for the specific roles of institutions within the process of impact generation and transmission.[9] The central components of this framework are: the *institutional* *ecology* principle, the *institutional decomposition and analysis* (IDA) approach [similar to that of E. Ostrom (1990)], the *ex-ante* approach, and the *adaptive instrumental evaluation* (Tool, 1977; Kahneman and Tversky, 1984; Bromley, 1985). While these concepts are elaborated in detail by Saleth and Dinar (2004) and described briefly in Annex A, let us note here how they are used to set the analytical framework for evaluating the institution-impact interaction in the present context. The institutional ecology principle enables one to view regional or river basin level institutions as a nested and interlinked system embedded within a given physical, social, and political economy setting. The IDA framework allows an analytical unbundling of both the impact transmission process and the regional or basin institutions (i.e., those related to water, land, agriculture and environment). The unbundling can identify the key impact pathways and trace the relevant institutional configurations operating beneath the pathways associated with different development programs. As we will show later, the 'adaptive instrumental evaluation' is used to provide theoretical support and practical justification for the reliance on perception-based *ex-ante* qualitative information collected from a sample of stakeholders.

As we adopt the framework of Saleth and Dinar (2004), we also need to introduce some important adjustments. The needed adjustments are:

First, institutional evaluation is to be specialized within a regional context (e.g., river basin or other compact regions), where it is easier to (a) identify relevant development programs, which can be completed, ongoing, or planned, (b) trace the major and theoretically possible impact pathways of these programs, (c) map all the relevant institutions operating at various points of these impact pathways, and (d) evaluate the development impacts and institutional roles in various paths with contextual information.

Second, the evaluation is to be extended to cover not just water institutions but also the land, agricultural, rural, and economic institutions within an integrated framework.

And, third, the evaluation has also to be performed within the framework of a multi-dimensional institution-impact matrix, which captures the major impact pathways of different development programs, the roles of the underlying development, institutional, and impact variables, and the ultimate implications for the development goals. The derivation of this institutional-impact matrix, including its analytical implications, is illustrated in the following section.

3.3. Institution-Impact Matrix

The institution-impact matrix translates the conceptual model shown in Figure 2 into an operational form. This matrix captures the functional relationships and synergy among the impact pathways of development programs, the underlying institutional configurations, and the development goals. To illustrate how this institution-impact matrix can be derived for the context of multiple development programs, let us take food security as the development goal and the following three as the candidate development programs, i.e., water development project (or dam construction), introducing a new crop variety, and watershed development for land/soil improvement. These three programs are related to each other not only in terms of their development synergies but also in terms of their direct or indirect impacts on the development goal, i.e., food security, and also on its three sub-components, i.e., income (employment), food prices (output), and sustainability (resource use efficiency). The next step is to identify the major impact pathways of these three programs and characterize the possible institutional configurations that shape these pathways. Given these impact pathways and their institutional configurations, the next step is to link them with the income, price, and resource components (or the intermediary targets) of the food security goal. As we put them together in a matrix form, as shown in Figure 3, we obtain an institution-impact matrix, which gives a generic operational form for the conceptual model depicted in Figure 2.

Let us note few points that will enhance our understanding of the institution-impact matrix. First, it is only to simplify its exposition that the matrix includes only the main impact pathways of the development programs. Since the impacts in each of these pathways are transmitted through several routes, there will be more rows than five, each with different institutional configurations.[10] Second, although each of the impact pathways obviously involve the physical, agronomic, and economic variables, they are not shown in the matrix partly to avoid expositional complications and partly to highlight what sort of institutional elements can be involved in these impact pathways. Third, the institutional configurations specified for different impact pathways are not exhaustive but only illustrative. It only shows how different institutional configurations are involved in the generation and transmission of impacts through various pathways. Fourth, although the rows in Figure 3 show only the generic institutional aspects, it is possible to identify one or more specific variables to represent these aspects. With such variables as well as the variables underlying various impact pathways, it is also possible to characterize the interaction between institutional and impact variables.[11] And, finally, even though the institutional configurations are common across impact pathways, the relative impacts of individual institutions in these configurations can be different, depending not only on the non-institutional variables with which they interact but also on the sub-components to which they are related.

The points noted above suggest that each row of the matrix implicitly has additional rows representing the various possible impact routes underlying different impact pathways. Since we have three intermediary target goals in this example, each of these rows also involves three separate but related causal relationships. That is, in these relationships, the impact and institutional variables will form the independent variables and the variable(s) representing the three goals will be the dependent variable. In this sense, all the rows corresponding to each of the three development programs can, in principle, be translated into an empirically testable set of relationships. These relationships or equations capture the interactions among the development programs, existing institutions, the interim impacts, and the ultimate impacts on the final development goal. Obviously, the dimension of the matrix or the number of these equations depends on the number of development programs, the impact pathways and their underlying impact routes, and the sub-goals being considered. But, the key point to note here is that in view of the intrinsic relationships among the development, institutional, and impact variables both within and across equations, there is a structurally linkage among equations. This fact allows us to embed all the equations into a single but long chain equation.

To demonstrate how the set of implicit equations within the institution-impact matrix is transformed into a single equation, let us define the following sets of four equations:

$\underline{D}_d = d(\underline{D}_d^{-p}, \underline{N}_d)$ .... [A]
$\underline{N}_n = n(\underline{N}_n^{-p}, \underline{D}_n)$ .... [B]
$\underline{M}_m = m(\underline{N}_m, \underline{D}_m, \underline{M}_m^{-p})$ .... [C]
$G = g(\underline{M}_g)$ .... [D]

[A] represents a set of equations capturing the effects of the vectors of independent development variables ($\underline{D}_d^{-p}$) and institutional variables ($\underline{N}_d$) on the vector of dependent development variables ($\underline{D}_d$). Similarly, [B] represents a set of equations that capture the effects of the vectors of development variables ($\underline{D}_n$) and institutional variables ($\underline{N}_n^{-p}$) on the vector of dependent institutional variables ($\underline{N}_n$). [C] represents a set of equations capturing the effects of the vectors development variables ($\underline{D}_m$), institutional variables ($\underline{N}_m$), and independent impact variables ($\underline{M}_m^{-p}$) on the vector of dependent impact variables ($\underline{M}_m$). But, [D] is a single equation capturing the effects of the vector of impact variables ($\underline{M}_g$) on the final Goal (G). Having specified the system, let us note four points. First, the vector $\underline{X}_x^{-p}\ \forall X = D, M, N;\ x = d, m, n$ is actually a subset of the vector $\underline{X}_x$, which covers only the independent variables within the larger set. Second, the development programs, institutional variables, and their multifarious impacts on development goals are all represented by suitably defined variables appearing on both side of the equations. Third, the total number of equations underlying the system defined by [A]-[D] will be: $1+d+m+n$. Finally, but more importantly, the equations within the system have a clear sequential linkage among them. Given these points, it is easy to show the system defined by [A]-[D] can be reduced into a single equation:

$G = g(m(n(\underline{N}_n^{-p}, \underline{D}_n),\ d(\underline{D}_d^{-p}, n(\underline{N}_n^{-p}, \underline{D}_n)),\ \underline{M}_m^{-p}))$ ....[E]

This equation, a mathematical replica of the institution-impact matrix, is an important analytical and empirical tool. When an equation of this form is empirically specified and statistically estimated, it can provide very valuable theoretical and policy insights both on the internal dynamics of institution-impact interaction and on the extent and flow of development synergies and institutional impacts. The empirical derivation and application of the framework set by [A] to [E] will be illustrated in the case of the Kala Oya Basin in Sri Lanka.

4. The Empirical Context: The Kala Oya Basin, Sri Lanka

The development and application of the institution-impact assessment methodology is demonstrated here by considering the institutional and development setting of the Kala Oya Basin in Sri Lanka (Figure 4). The Kala Oya Basin, which is one of the 108 basins in Sri Lanka, covers an area of 2,873 square kilometers and supports a population of about 0.41 million. Of the total land area of 287,303 hectares (ha), far less than a third is cultivable due to land slope and quality issues and other soil-related problems and water-related constraints. Paddy cultivation and home gardens with coconuts and fruit trees account for 40 percent of the cultivated area (de Silva et al., 2006). The average farm size is only about one ha in areas under minor irrigation and dryland farming and less than half a ha in areas under major irrigation schemes. In addition, only 27 percent of the population own a homestead and 11 percent of the population own neither a homestead nor land (see Bandara, undated). On the demographic side, increasing population density, out-migration, and aging are major issues.

Water scarcity is a serious problem due to low level and seasonal pattern of rainfall as well as groundwater quality problems. The Basin is generally dry for the most of the year with the rainfall ranging from less than 50 mm to about 300 mm. While the high rainfall level occurs only during October and November, the low level occurs in February, March, June, July, and August. With an annual local inflow of about 343 million cubic meters (mcm), the Basin also receives an annual diversion of about 480 mcm from the Mahaweli system. But, given the total demand of 1695.28 mcm, there is still a major supply short fall, creating a serious water scarcity problem for the basin (see Bandara, undated; de Silva et al, 2006). The issue is further complicated by serious groundwater quality problems caused by hardness, fluoride content, and iron concentrations. Of the basin groundwater resources, 74 percent is affected by various forms of fluoride problems and 40 percent is affected by unsafe iron concentrations (Bandara, undated).

The incidence of poverty remains substantial in the basin. For example, in the Anuradhapura district, which accounts for half of the basin area, the percentage of people below the official poverty line (Rs. 1423 or US$14/capita/month) was estimated to be 20 percent during 2000-01 (de Silva et al., 2006). In addition, 44 percent of the families in the basin rely regularly on *Samurdhi,* the safety net program of the government for the poor. Closely related to the poverty issue, food insecurity is also a serious problem, as many villages in the basin area fall under the most vulnerable categories of food insecurity (DCS and WFP, 2005). A more detailed review of the Basin's poverty level and the strategic reasons for its selection for our case study can be found in Saleth et al. (2007).

5. EMPIRICAL SPECIFICATION OF THE MODEL

For the empirical translation of the institution-impact matrix in Figure 3, we need to specify the development goal, select the candidate development programs, and identify the relevant set of institutions. Considering the poverty levels and food insecurity conditions in the study area, we obviously selected food security as the development goal for analysis. This goal, which is directly related to the hunger reduction target of the first MDG, is also one of the priority goals of policy set by the government in Sri Lanka. As to the candidate development programs, we selected three water and food-related programs relevant for the study region. They are: system rehabilitation (already completed) and bulk water delivery (being piloted), and crop diversification (potentially relevant).[12] This choice allows us to evaluate not only the interaction between the water-related programs but also their implications for other programs in a related sector such as agriculture. Given the choice of the development goal and programs, it is now possible to trace and delineate some of the major pathways through which these programs could affect food security. Given these impact pathways, it is also possible to identify the relevant set of institutions (i.e., water, land, agriculture, and food-related legal, policy, and organizational aspects) that are likely to affect the generation and transmission of impacts at different points of the impact transmission process.

Figure 5 depicts these impact pathways and their underlying institutional configurations.

Before interpreting Figure 5, it is important to recognize that it shows only one of the many possible ways of conceptualizing the impact pathways of the development programs. But, depending on the details required, it can be made richer (and also be made more complicated) by adding more development programs, impact pathways, and the institutional and impact details. Even though Figure 5 covers only a few of the many possible impact pathways, it is still able to capture the most important and also policy-wise more relevant among these pathways. Notably, these pathways will be different depending on the kind of development programs, regional contexts, and final development goal being considered for evaluation. More importantly, the flow diagram of impact pathways always assumes a particular environment as characterized by the physical, economic, and institutional context of the region being evaluated. Any change in this environment is likely to affect the relationship among the variables characterizing the impact pathways being considered. These changes can be captured either through observed or *ex-ante* information.[13]

With the points noted above, we can see in Figure 5 how the development programs interact with each other and with the physical and economic aspects in order to generate their development impacts and synergies. In the impact transmission process, we can also identify which institutions influence the process at what points. While it is common to read Figure 5 from left to right in line with the direction of pathways and impact flows, for analytical convenience, it is useful to move recursively, i.e., starting first with the development goal, then, tracing back to its immediate and intermediate determinants till we reach finally the development program. In doing so, we can identify all possible impact pathways and channels evident in Figure 5. In view of their functional and sequential linkages, these pathways and channels can be characterized as formal relations using appropriate chains of development, institutional, and impact variables defined in Table 1.[14] That is, using these variables, Figure 5 can be equally represented in a mathematical from as a system of linked equations. But, before attempting this, it is instructive to understand the nature, format, and logic of the variables listed in Table 1.

As can be seen from Table 1, the model includes one development goal variable, three variables for the development programs, 17 impact variables, and 11 institutional variables.[15] Obviously, the variables differ considerably in terms of their unit of measurement, amenability for observation, and availability of data. To avoid the problems due to their diverse features, we conceive all the variables essentially in a notional and qualitative sense to be evaluated on an interval of 1-10, with 1 being the lowest and 10 being the highest.[16] In this format, the variables capture only the overall perception of the evaluators (i.e., sample stakeholders) as to their status, change, effectiveness, or impact. For example, the food security variable represents only an overall perception of its notional status considering implicitly, the adequacy and quality of food consumption across income/social groups. It is considered to be affected by three proximate variables, i.e., income, food prices, and food availability. Similarly, the variables representing the development programs are considered to capture their overall impact potential. Since the impact potential is intimately linked program planning and implementation, the program-related variables also implicitly capture the effectiveness of development administration.

Institutional variables capture the status, effectiveness, or impact of institutions with respect to different impact pathways. For example, the variable LANTENUR captures the conduciveness of land tenure (farm size and ownership) to crop pattern changes, land productivity improvements, etc. CUSINSTN captures the effects of local customs and conventions on economic and social aspects such as crop choice, wage fixation, water sharing, and community management. Similarly, WATINSTN represents the effectiveness of the organizational aspects related to water allocation and distribution within the system level whereas WAGELAWS represents the effectiveness of legal provisions related to minimum wage and working conditions. Likewise, the other institutional variables capture the effectives of other legal, policy, and organization-related institutional aspects in different contexts. The impact variables, which are essentially physical and economic in nature, capture the actual or expected changes due to the impacts of programs and institutions in different stages of the impact generation and transmission process. Among the income variables, a distinction is made between AGLINCOM and FAMINCOM with the former covering only the income from agriculture and the latter covering both agricultural and livestock incomes). But, LABINCOM, the income of laborers, covers wage and livestock incomes. These three income variables are needed to capture the differential income potentials between those with and without land and livestock. Given the set of variables listed in Table 1, the institution-impact framework in Figure 5 can be formally represented in a mathematical form with a set of following 21 equations that comprise the system model of institution-impact interaction.

BULKWATD = f_1 (SYSREHAB, LANTENUR) .... [1]

CROPDIVR = f_2 (BULKWATD, FAMINSTN) .... [2]

CROPATEN = f_3 (CROPDIVR, LANTENUR, CUSINSTN) .... [3]

WATINSTN = f_4 (BULKWATD, LANTENUR, CUSINSTN) .... [4]

WATPRODY = f_5 (CROPATEN, WATINSTN, FAMINSTN) .... [5]

LANHELTH = f_6 (CROPATEN, WATPRODY, LANTENUR) .... [6]

LANPRODY = f_7 (CROPATEN, LANHELTH, FAMINSTN) .... [7]

FEDSUPLY = f_8 (CROPATEN, CUSINSTN) .... [8]

LIVSTOCK = f_9 (FEDSUPLY, TRDPOLCY) .... [9]

NFAMENTS = f_{10} (CROPATEN, RDVPOLCY) .... [10]

LABPRODY = f_{11} (LANPRODY, CROPATEN) .... [11]

WAGERATE = f_{12} (LABPRODY, NFAMENTS, WAGELAWS) .... [12]

RURALEMP = f_{13} (LANPRODY, WAGERATE, NFAMENTS, LIVSTOCK) .... [13]

CULTCOST = f_{14} (CROPATEN, WAGERATE, FAMINSTN, SUBPOLCY) .... [14]

AGLINCOM = f_{15} (LANPRODY, CULTCOST, MKTINSTN) .... [15]

FAMINCOM = f_{16} (AGLINCOM, NFAMENTS, LIVSTOCK) .... [16]

LABINCOM = f_{17} (RURALEMP, NFAMENTS, LIVSTOCK, SAMPOLCY) .... [17]

FOODPROD = f_{18} (CROPATEN, LANPRODY, WATPRODY) .... [18]

FOODAVAL = f_{19} (FOODPROD, TRDPOLCY, MKTINSTN) .... [19]

FOODPRIC = f_{20} (FOODPROD, PRICREGL, MKTINSTN) .... [20]

FOODSECT = f_{21} (FOODAVAL, FOODPRIC, FAMINCOM, LABINCOM) .... [21]

It can be verified that each of these equations correspond to one of the 21 impact pathways evident in Figure 5. The configuration of variables chosen for each equation is based on two considerations: (a) the functional relationship expected between them and the independent variable as per economic reasoning and (b) the need for avoiding linkages among independent variables to minimize the scope for the econometric problem of multicollinearity. The equations are arranged sequentially, starting with the initiation and implementation of the development programs, then, with their impacts in the order of their occurrences, and finally, ending with the impact on the ultimate development goal, i.e., food security. Figure 6 depicts the pattern of sequential linkages evident among the model equations. The order in which the equations are sequenced captures the relative position of different layers within the upstream-downstream continuum of impact transmission. Given the functional linkages among variables and sequential linkages among equations, the impact and institutional variables can be hierarchically arranged by tracing their role and positions both within and across the impact pathways. As argued in section 3.3 and will be show in section 8, this sequential feature is used to derive the single-equation reduced form for system model and also to trace size and flow of the system-wide impacts of marginal changes in different variables.

Another important aspect of the system model is that of the 32 variables, the 11 underlined variables are independent or exogenous, which includes one of the development programs (SYSREHAB) and all the institutional variables except water institution (WATINSTN). But, the remaining 21 variables are dependent or endogenous covering 17 impact variables, two development variables representing respectively the two programs of CROPDIVR and BULKWATD, and one institutional variable representing WATINSTN. From an econometric perspective, let us also note that given the way all the 21 equations are specified in terms of the configuration of endogenous and exogenous variables, they satisfy both the rank and order conditions necessary for their econometric identification and unbiased estimation (Kennedy, 1987).[17]

6. DATA SOURCES

The system model is econometrically consistent and intuitively appealing, but it has a major empirical challenge. This is because consistent and comparable data on both the development, institutional, and impact variables are very difficult to obtain. It is certainly possible to acquire observed data on some of the impact variables (e.g., productivity, employment, income, and wage rates) through, for example, published records or primary surveys. But, such data can represent only the past impact of an already implemented development program and can not capture the synergy from the expected impacts of ongoing and planned program. Still more serious are the difficulties in getting the data on institutional variables, especially on their diverse but specific roles in the generation and transmission of development impacts.

The absence or lack of data on most variables does not, however, mean a complete absence of information. Highly relevant information is constantly processed, coded, and stored in the minds of people involved in the development process either as planners and implementers or as beneficiaries. Such real but latent information, embodied in individuals, can be tapped through a carefully designed and conducted stakeholder surveys. This form of survey data, though based on stakeholders' perception, have many desirable properties often missed by the so called objective or observed data. For example, unlike observed data characterizing a past and static situation, the perception-based data can capture and synthesize objective, subjective, and aspiration-related information. Similarly, they can also capture the *ex-ante* and dynamic elements. It is also theoretically legitimate in view of the subjective nature of institutions (Commons, 1934; V. Ostrom, 1980; Douglas, 1986; E. Ostrom, 1990) and the roles that the 'subjective model' of the 'agents of institutional change' play in institutional change and performance (North, 1990). As a result, there is a long tradition of using such data for institutional analysis (e.g., Knack and Keefer, 1986; Gray and Kaufmann, 1998; Barret and Graddy, 2000; Kaufmann, Kraay, and Mastruzzi, 2006). As noted already, qualitative data are also used in the few impact assessment methods discussed earlier (Neubert, 2000; Coudouel, Dani, and Paternostro, 2006).

Perceptions can be used as an evaluation mechanism not only to synthesize objective, *de facto*, *ex-ante*, and subjective information but also to bring variables in different domains into a common evaluation context. In view of these properties, perception-based information is similar in format and quality to those derived from alternative non-market data generation techniques such as ‘Delphi’, ‘Contingent Valuation’, and ‘Stated Preference’ (see Saleth and Dinar, 2004). More importantly, perception can also be used to operationalize the ‘adaptive instrumental evaluation’ approach, where the outcomes are evaluated in positive and relative terms with respect to reference points that are not static but change with learning and expectations (Tool, 1977; Kahneman and Tversky, 1984; Bromley, 1985) Thus, the comparability of perception-based information from different stakeholders can be ensured when their reference points are, more or less, similar, if not common. This reference point can be related to the minimum and maximum values or the best and worst performance, which are either expected or observed in practice. Given this fact and the possibility for convergence in understanding and evaluation standards through interaction and learning, it is reasonable to use stakeholder-based information for empirical evaluation of the model of institution-impact interactions.

While the rationale and justification for the use of perception-based data are clear, to collect such data with good quality and consistency, it is important to follow few steps. First is the clear specification of the spatial context of evaluation. Since we consider multiple institutions that transcend sectoral boundaries and vary across provinces, it is essential to select the study area to be entirely within a single jurisdictional boundary. It is for this reason that our evaluation is confined to the North Central Province, which accounts for 80 percent of the Kala Oya Basin. Second is the selection of suitable sample. The sample of stakeholders selected has to be sufficient enough to capture diversity and balanced enough to minimize bias. On this count, the sample selected here covers 67 individuals, who are directly involved in, or familiar with, the development planning, implementation, and evaluation in the Kala Oya Basin.[18] They include high-ranking officials from government departments working at different spatial levels (32), researchers, academics, and NGO members (32), and farmers and community leaders (3).[19]

The final but more important aspect is the design and administration of the survey instrument used for eliciting the perception-based information. To collect the information on all the 32 variables included in the model, a special survey instrument was developed and administered to sample stakeholders in May 2006. The survey instrument is included as Annex B. It shows how different variables are defined and how their values were derived from the answers to one or more questions. These questions were presented in such a way as to elicit information on a given variable from different angles and perspectives. In almost all cases, the values of the variables were obtained as the average of the values for related questions.[20] Table 2 presents the descriptive statistics for the 32 variables.

7. Results and Interpretations

Before presenting the econometric results, it is instructive to note first the way the model and the equations are specified. In order to select the appropriate functional forms for the model equations, the specification test suggested by Hausman (1978) was performed. This test was used to compare two models both with constant terms but with different functional forms, i.e., linear and log-linear. Since this test suggested that the linear specification yields a more efficient and consistent estimates, we adopted this specification for all the equations in the model. We also performed a test for multicollinearity.[21] Although multicollinearity was not a serious problem with the model variables, we also tried to ensure that this is also true at the level of individual equations. The correlation matrix for variables at the equation levels suggest that in many equations, a few variables are highly correlated mainly with the constant term. To eliminate this potential for multicollinearity, we estimated all equations without the constant term.

With the same specification, i.e., the linear form with no constant term, we have also estimated two versions of the model of institution-impact interaction. The first is a single equation model, where food security is postulated as a simple linear function of all the remaining 31 development, institutional, and impact variables. This simple model, in fact, captures the conventional approach, which assumes away the specifics and dynamics of institution-impact interactions. The second version is the system model, which specifically captures the mechanics of impact generation and transmission in terms of 21 sequentially linked equations. By comparing the two models and their results, we can show the additional insights from a more realistic modeling and evaluation of the process of institution-impact interaction and also the specific points where different institutions have their influence on and interaction with other impact variables. As to the estimation procedure, the single equation model was estimated using the Ordinary Least Square (OLS) method while the system model was estimated using the Three-Stage Least Squares (3-SLS) approach.

The OLS results of the single equation model, which captures the conventional approach to institution-impact interaction, are presented in Table 3. Since the single equation model postulates the development, institutional, and impact variables to directly influence food security, it is not able to characterize the actual paths and mechanics of the interactions and impacts. Consequently, as can be seen from Table 3, the OLS results show that none of the institutional variables is statistically significant. This is also true with the variables representing the three development programs. Even among the 17 impact variables, only five are significant at 10 percent or better. These significant impact variables are: LABPRODY, WAGERATE, AGLINCOM, FAMINCOM, and LABINCOM. Notably, all of them, except AGLINCOM, have the expected positive effect. The negative effect of AGLINCOM, especially given the positive effect of FAMINCOM, is clearly inconsistent with expectation, as it suggests a negative association between agricultural income and food security. This inconsistency taken with the insignificance of institutional and development variables clearly suggests the potential for serious anomalies when a single equation model is used to describe the reality of a complex set of sequential and simultaneous interactions among the model variables. This problem gets still more serious because institutional roles are treated superficially or exogenously, missing the reality of their intricate and endogenous roles within development process.

In contrast, the system model results presented in Table 4 demonstrate the additional policy insights that can be derived with a more realistic treatment of institutions, especially considering their mediating roles both in the generation and transmission of development impacts. Since development impacts and institutions influence each other, the mediating roles can be seen better when the specific points at which these influences are fed into the process of impact transmission. From this perspective, the key aspect to note from Table 4 is the way both the institutional influences and the development impacts are transmitted across the equations. The operational mechanisms for such transmissions are the sequential linkages among the equations (see Figure 6). Given this fact, our interpretation of the results will proceed along the equations to show how the dependent variables in the initial and intermediate equations capture and transmit development synergies and institutional impacts onto the ultimate goal of food security. In the interpretation, we also show how the relative size and statistical significance of the coefficients of different institutional and impact variables can be used to indicate the possible weak spots and missing links both within and across the impact transmission pathways.

Before proceeding, we can note that the results in Table 4 have the necessary econometric credentials, particularly in terms of their efficiency, consistency, and stability properties as ensured both by the specification test and multicollinearity correction. Despite a low R^2 for individual equations, the System R^2 is relatively high and the Chi-Square statistic is statistically significant, suggesting a strong overall explanatory power of the model as a whole. These econometric properties only suggest that the model has fitted well the data, but what is more important for the interpretation of the results are the econometric implications of the nature of the data source being used. Since the data is based on stakeholders' perception, the estimated coefficients of the model provide a statistical representation of the prevailing consensus on the nature and direction of the effects of different variables. For that same reason, the coefficients also summarize the effects of both the perceived objective reality and the revealed subjective expectation of sample stakeholders. It is with these points in mind that we interpret the equation-specific results along with their system level implications.

Equations [1] and [2] capture the potential impact synergies among the three development programs. These synergies are both positive and statistically significant. In Equation [1], SYSREHAB, the physical intervention that can improve the performance of water infrastructure, has a significant positive effect on the

BULKWATD, the institutional intervention that can improve water distribution. As can be seen in Equation 2, BULKWATD, in turn, has a significant positive effect on the agricultural intervention of CROPDIVR, suggesting that bulk water allocation enhances the prospects for crop diversification.[22] The role of institutional variable in these equations, unlike the LANTENUR in Equation [1], FAMINSTN in Equation [2] is significant and also has a positive effect. This suggests that land tenure is not at all a constraint for bulk water distribution whereas farm institutions related to input supply and extension have a facilitative role in crop diversification.

The results of equations [1] and [2] suggest that the infrastructural and institutional factors are conducive for crop diversification in the region. But, it is important to see whether such a diversification prospect is actually translated in terms of changes in existing crop pattern. Obviously, the extent of crop pattern changes depends not only on the effectiveness of the crop diversification program but also on the role of institutional factors such as land tenure and customary practices in crop choice. The results for Equation [3] show that all the three variables—representing both the CROPDIVR program and the CUSINSTN and LANTENUR institutions—have significant positive effects on CROPATEN. Since CROPATEN captures the extent the food crops dominate the existing crop pattern, the positive effects of both CUSINSTN and LANTENUR are understandable in view of the fact that both customs and farm size favor food crops. But, the positive effect of CROPDIVR means that the diversification program even when it is actually implemented in the region will not be able to alter existing food crop dominated crop pattern. In effect, this suggests the powerful role of customs and other economic and institutional constraints.

Equation [4] captures the effects that bulk water delivery, land tenure, and customary institutions have on the overall functioning and performance of water institution. As expected, the program of bulk water delivery has a positive and highly significant effect on water institutions, suggesting its potential role in strengthening user organizations and promoting orderly water distribution. But, both the customary practices and land tenure system have a negative but non-significant effect, which means that these two institutions do not pose any problem to the functioning of water institutions. Equation [5] evaluates the relative role of factors affecting water productivity. The results for this equation shows that of the three variables postulated to affect WATPRODY, only CROPATEN is significant with a positive effect. Despite their positive effects, both WATINSTN and FAMINSTN remain insignificant. This means that water productivity is perceived to depend not on the water and farm-related institutions but only on the food-crop dominated crop pattern. This result seems to contradict the expectation that water productivity, especially in value terms, will be higher with non-food and commercial crops. But, given the ineffectiveness of crop diversification program, the weakness of water and farm institutions, and the low physical productivity and poor market institutions for non-food crops, this result need not be surprising.

It can be seen in Equation [6] that of the three variables expected to affect LANHELTH, both CROPATEN and WATPRODY have significant positive effects whereas LANTENUR has a negative but insignificant effect. This result is understandable partly because the biomass of cereals, especially paddy straw, is commonly used for mulching and partly because higher water productivity is likely to lead to efficient water use favorable for soil conservation. Equation [7] provides statistical evidence for the relative role of physical, agronomic, and institutional factors in determining land productivity. The result shows that only the two physical and agronomic variables, i.e., land and soil health and crop pattern, are significant with the expected positive effect. Notably, FAMINSTN, the variable capturing the overall effectiveness and performance of farm input and extension institutions, has a negative but non-significant effect. This clearly means that these institutions, though have the capacity to perform routine roles as well as to support crop diversification (see Equation [2]), are not tuned well to make a difference either in water productivity (see Equation [5]) or in land productivity (see Equation [7]). From a policy perspective, the results also suggest that the farm institutions related to input supply and extension systems need to be reoriented and strengthened, particularly to enhance their performance in their productivity enhancing roles.

The results for Equation [8] show that of the two variables expected to affect the feed supply potential, only CROPATEN has a positive and statistically significant effect on FEDSUPLY. CUSINSTN, the other institutional variable included in this equation has a positive but insignificant effect. This result suggests that the cerealdominated, especially paddy-dominated, crop pattern obviously contributes to feed and fodder supply in terms of crop residues whereas the potential roles of customary institutions in preserving areas and maintaining rules for open grazing and biomass collection need to be strengthened. This is another instance of institutional gaps, the correction of which requires policies and programs to revive and strengthen local level customary institutions for managing common pool resources. The importance of enhancing the supply of feed supply from a better utilization of the biomass both from crop residues and from common grazing lands is underlined further by the results for Equation [9]. Of the two variables included in this equation, only FEDSUPLY is significant with the expected positive effect on the prospects for livestock development (LIVSTOCK). But, TRDPOLCY, the policy-related institutional variable capturing the effects of the policy of importing milk and dairy products, though widely considered to be a major deterrent for the livestock development in the country, is not at all significant.

The results for Equation [10] reveal the linkage between farm and non-farm activities observed in the study region. The statistically significant positive effect of CROPATEN suggests that existing crop pattern dominated by food crops has a significant positive effect on the prospects for rural non-farm enterprises. This is mainly due to the fact that most non-farm activities observed in the study region are linked to the processing and marketing of food crops, especially paddy. Such dependence is obviously not conducive for the expansion and diversification of the rural non-farm sector. Nevertheless, the significant positive effect of RDVPOLCY indicates that active rural development policies have the potential to substantially contribute to the growth and diversity of rural non-farm options. Equation [11] suggests that labor productivity depends not on land productivity but mainly on crop pattern. Yet the direct relation between crop pattern and labor productivity requires a more in-depth interpretation.[23] The lack of association between the two productivity variables is easy to explain. That is, with similar crop patterns and productivity levels, land productivity may not be able to explain the variations in labor productivity.

In Equation [12], among the three variables postulated to affect WAGERATE, only NFAMENTS and WAGELAWS are significant with the expected positive effects.

Notably, LABPRODY is not significant suggesting that prevailing wage rates are not closely related to labor productivity. In contrast, non-farm activities have a strong effect on wage rates due to their influence on rural labor demand and thus rural wage levels. Similarly, the institution of formal state regulations and informal local conventions governing wage levels and working conditions also have a positive effect wage rates. In equation [13], all variables with the exception of WAGERATE have a statistically significant effect on RURALEMP. As expected, LANPRODY and NFAMENTS have a positive effect whereas LIVSTOCK has a negative effect. Particularly, land productivity, which had an insignificant effect on labor productivity in Equation [11], has here a significant positive effect on rural employment. The positive employment effect of NFAMENTS is consistent with the results in Equation [12]. The negative coefficient for LIVSTOCK suggests that livestock expansion, though good for rural income, has a negative effect on rural employment.[24] Though non-significant, the negative coefficient of WAGERATE suggests that higher wage rates can constrain rural employment.

The results for Equations [14] show that cultivation cost has a strong positive linkage only with the wage rate. This is consistent with the general concern in the study region about the cost implications of higher wage rates. Notably, all the other three variables, i.e., CROPATEN, FAMINSTN, and SUBPOLCY, have negative but non-significant effect on cultivation cost. Although not significant, the negative effect of FAMINSTN and SUBPOLCY does suggest their potential roles in reducing cultivation costs. Indeed, this is another case where improving the performance of institutions (i.e., farm institutions, especially in terms of their roles in delivering farm inputs at reasonable cost and subsidy policy, especially in terms of their design and targeting) can enhance the development impact. Turning to Equation [15], AGLINCOM, which represents the income only from farm operations, is influenced positively by both land productivity and cultivation cost. The positive effect of CULTCOST, unlike that of LANPRODY, is unexpected, particularly given the prevailing concern in the study region, in particular, and the country, in general, regarding the economic viability of farming in the face of rising cultivation costs. But, it is possible to have rising levels of crop income coincided with increasing cultivation costs, as long as land productivity and crop price levels have a dominant and neutralizing effect.

Equations [16] and [17] evaluate the relative size, sign, and significance of the relative effects of the factors influencing respectively the income levels of farmers and landless farm workers. Equation [16] evaluates the relative effects of AGLINCOM, NFAMENTS, and LIVSTOCK on farmers' income (FAMINCOM). The results show that although all three variables are positive, only NFAMENTS and LIVSTOCK are significant. This is not to be interpreted as agricultural income is unimportant for farmers. What this means is the fact that with a more or less stable income from farming, the other two sources of income are more important in terms of their incremental impact on farmers' income. As can be seen from Equation [17], the incremental impact of these two income sources of farm workers is still more pronounced, suggesting livestock and non-farm options are much more important as income sources for landless workers. Importantly, RURALEMP has a significant negative effect. This may be partly due to the inverse association between wage rates and rural employment, as seen in equation [13], and partly due to the fact that more farm employment reduces the days available for non-farm and livestock activities causing, a fall in total labor income. Notably, SAMPOLCY, the variable representing payments under *Samurdhi*, the government's poverty alleviation program meant for the poor and landless, has a positive but insignificant effect. From an overall perspective, the results of equations [16] and [17] suggest that despite their low level of development in the study region, non-farm and livestock sectors are very important income sources for both small farmers and rural workers.

The next set of three equations captures the relative role and significance of the variables affecting respectively the three key determinants of food security, i.e., food production, food availability, and food prices. In Equation [18], the statistically significant positive effect of CROPATEN and LANPRODY indicates that a crop pattern dominated by food crops and a higher level of land productivity contribute directly to food production. The results for Equation [19] show that food production, trade policy, and market institution all have a positive effect on food availability. However, of these three variables, the effects of only the first two are statistically significant suggesting their relative importance in determining food availability. The results for equation [20] are contrary to expectation because food production, price regulation, and market institutions, which are supposed to discipline food prices, are all significant with a positive effect. However, this result is not entirely inconsistent as it only illustrates how food prices can continue to rise despite increasing food production either due to hoarding or greater gap between food demand and supply. The results also suggest that the procurement, distribution and price related regulations as well as the market mechanisms in the study area are not really effective in moderating food prices. Here is another case where an increase in institutional performance can vastly improve the development impact.

Equation [21] is the ultimate equation in the system, as it brings together various direct and indirect effects of the development, impact, and institutional variables flowing through all the previous equations and also link them with the final development goal of food security. The results for this equation show that all the four variables have the expected signs, though only FOODAVAL and FOODPRIC are statistically significant. The positive sign for FOODAVAL, FAMINCOM, and LABINCOM suggests clearly that better food availability and higher income will directly strengthen food security. The negative sign for FOODPRIC, on the other hand, means that lower (higher) prices will enhance (reduce) food security. But, as we consider the relative size of the coefficients, the price effect is much more important than the supply and income effects. Similarly, among the income variables, farm income is more important than labor income. This result is important as it shows that food security depends more on food prices and farm income than on food availability and labor income. Since food security is stronger among people with access to land than among those without that access, the results also underlines the food security significance of the access to land and other assets.

8. Evidence for Development Synergies and Institutional Effects

So far, our attention has focused mainly on the relative role and significance of the development, institutional, and impact variables in each of the individual equations within the system model. But, in view of the structural linkages among the model equations (see Figure 6), these local or layer-specific effects of the variables also have impacts not only on the subsequent layers of the system but also on the system as a whole. More importantly, as these impacts flow through the system, they can be magnified, neutralized, or even distorted by the role of other variables interacting in subsequent equations. With the system model and its coefficients, it is possible to develop greater insights into the dynamics of the impact transmission process. The dynamics of impact transmission can be evaluated both analytically and numerically using a reduced form single equation for the system model. This equation can be formed by using the structural linkages among the equations. The derivation of the reduced form equation is explained in Annex C. As can be seen, the reduced form equation shows food security, the ultimate dependent variable of the system model, as a function of all the previous equations with their characterizing variables and embedded linkages.

Since the reduced form is actually an equation of equations, when it is differentiated with respect to a given variable, the effect will not only be on the equation where this variable appears as an argument but also be on all subsequent equations where the dependent variable of this equation appears as an argument. As a result, the calculation of the total effect due to a change in a given variable involves either the multiplication of intermediate coefficients (when the relevant equations are embedded) or the addition of relevant coefficients (when the equations are separate). The former involves a single channel but the latter involves multiple channels. Thus, by differentiating the reduced form equation with respect to different variables and substituting the estimated coefficients from Table 4, we can numerically calculate how the marginal effects of different development and institutional variables are being captured at each equations and how these captured effects are consolidated at subsequent equations to get them finally transmitted into the ultimate equation. It is this exercise that is used here to trace the flow and quantify the impacts of development synergies and institutional effects on all the endogenous or dependent variables of different equations within the system. The results of this exercise with respect to three development programs are presented in Table 5 and the same with respect to 10 institutional variables are presented in Table 6.

While there is a derivative of the reduced form equation behind each cell in both tables, it will be quite complicated and lengthy to present all these derivatives. However, there is a simple and intuitive way to explain how the number in each cell of the both tables is derived in terms of the addition and/or multiplication of relevant coefficients from Table 4. For instance, the first cell in the first column of Table 5 shows the marginal effect of system rehabilitation on bulk water supply. Since bulk water supply is the dependent variable in the first equation of the system, the marginal effect here is just the coefficient of system rehabilitation, i.e., 0.886. Similarly, the second cell of the first column is the marginal effect of system rehabilitation on crop diversification. But, going by the specification of equations [1] and [2], system rehabilitation affects diversification not directly but only indirectly via bulk water supply. Thus, using the chain rule, the relevant marginal effect will be 0.526, which is the product the coefficient of system rehabilitation in the first equation (0.886) and that of bulk water supply in the second equation (i.e., 0.594). Similarly, the third cell of the first column shows the marginal effect of system rehabilitation on crop pattern, which is transmitted indirectly via the two variables, i.e., bulk water supply and crop diversification. Again, using the chain rule, this marginal effect (0.231) is obtained by multiplying the coefficients of system rehabilitation in the first equation (0.884), that of bulk water supply (0.526) from the second equation, and that crop diversification (0.438) from the third equation. Similar procedure of multiplication in the case of indirect effects and addition in the case of multiple effects are used to obtain the values of marginal effects in the remaining cells of Table 5. Needless to add, similar explanation also applies to the values in Table 6. Let us also note that in both tables, we also reported the row and column totals. The row total indicates the total impacts captured by each of the 21 endogenous variables whereas the column total indicates the total impacts generated by the development programs in Table 5 and that by the institutional variables in Table 6.

Table 5 shows the size and flow of the marginal impacts of the three development programs across the equations. These marginal impacts cover both the effects of synergies among the programs and the effects of improved effectiveness and performance of individual programs. Notice, however, that the flow of the synergy among the programs is unidirectional, i.e., from system rehabilitation to bulk water policy and, then, from the latter to crop diversification. This is essentially due to the particular way the interactions among the programs are modeled. That is, the system rehabilitation is considered to facilitate bulk water delivery and the latter, in turn, to influence crop diversification, but crop diversification is modeled to influence neither of the other programs. Considering this fact, the value of synergy derived by BULKWATD from system rehabilitation is 0.886. But, CROPDIVR derives synergies both directly from bulk water delivery policy (i.e., 0.594) and also indirectly from system rehabilitation (i.e., 0.526). The value of direct synergy is simply the value of coefficient for BULKWATD in Equation [2] whereas the value for the indirect synergy is obtained by multiplying the coefficients of SYSREHAB (0.886) in Equation [1] and BULKWATD (0.594) in Equation [2]. Since crop diversification, unlike bulk water delivery policy, has two routes for synergies, its total development synergy is equal to 1.200. As a result, crop diversification receives more synergy than that of bulk water delivery policy. However, the development externalities for both bulk water delivery policy and crop diversification are substantial and from a policy perspective, they can be improved with a better and more effective monitoring and implementation of related development programs.

More importantly, the development synergies flow throughout the system because they are being captured by many, if not all, the intermediate variables and finally transmitted to the ultimate variable of food security. As noted above, besides the synergy effects, these variables also capture the effects of improvement in the performance of the individual programs as well. That is, the effects captured by the intermediary and final variables are actually the combined effects of both the individual and collective performance of the three programs with an effective implementation and coordination. In Table 5, the combined effects as well as the sum of the total effects derived by some of the variables are substantial while those derived by others are very small. For instance, water institution derives the highest combined effects from both system rehabilitation (0.754) and bulk water delivery (0.851). On the other hand, food security, food availability, food price, farmers' income, and labor productivity capture relatively less of the impacts of all the three programs. In terms of the total synergy derived from all the programs, land productivity comes first with the value of 2.206, followed by water institution (1.605), cultivation cost (1.350), labor income (1.306), and water productivity (1.287). Among the programs, in terms of their total synergy effects, bulk water delivery policy with a value of 7.200 is relatively more important than the other two with a value of around 6.500.

Table 6 shows the size and flow of the impacts of the institutional variables, which are exogenous to the model.[25] The impacts of these variables are captured both directly and indirectly by the 21 endogenous variables or the dependent variables of the 21 equations. The institutional variables obviously differ in terms of their interaction with the development and impact variables depending on their location in the impact pathways. As a result, the impacts of some institutional variables are captured in many equations while the impacts of others are captured only in few equations, especially those capturing the interactions further down the impact pathway. For instance, land tenure, customary institution, and farm institution affect almost all the equations, but market institution, price regulation, trade policy, subsidy policy, and *Samurdhi* policy affect only few equations. The total impacts generated by the institutional variables affecting many equations are likely to be larger than those affecting only a few equations.

In terms of their relative impacts on food security, some of the institutional variables affecting a few equations (e.g., market institution, price regulation, and trade policy) have a relatively larger impact than those affecting many equations. These results highlight two very important aspects. First is the role of impact dissipation within the impact transmission process due to their long impact chains, weak impact links, and *en route* impact distortions. Second is the role of relative proximity or shorter impact chains associated with a few institutional variables to the final and proximate goals. It is the impact dissipation that explains why the institutional variables related to land tenure, custom, and farm input supply and extension could not sustain their substantial initial impacts. On the other hand, it is the role of relative proximity that explains why the institutions related to market, price, wage, and trade have a larger impact on food security. From a policy perspective, while it is important to focus on institutions with proximate effects, it is important to address the issue of impact dissipation by locating and strengthening the weak links. From the results in Table 3, it is possible to locate these weak links by looking at what variables have caused such dissipation in which equation.

From an overall perspective, the results in Table 6 suggests that the institutions having a major impact on food security are market institution, trade policy, price regulation, and wage laws. This is mainly due to their direct impact on food supply, food price, and wage income. Notably, despite their positive intermediary impacts, the food security impacts of land tenure, rural development policy, and subsidy policy are all negative, suggesting their ineffectiveness. Although customary institution, farm institution, and land tenure have a larger impact on the system as a whole, their food security impact is either low or negative. Among them, customary institutions are not that easy to change through deliberate policies while land tenure is politically difficult to change. Practical considerations require a greater policy attention on the reorientation of farm input and extension institutions, which are likely to be easier to change. This is particularly so given the substantial contributions that farm institutions can potentially make.

As we compare the total effects of development programs and institutions as captured by different endogenous variables in tables 5 and 6, we find the development impacts are more than the institutional effects in most cases. Notably, in the case of water institution, the total institutional impact is even negative. But, it is interesting to note that in seven cases including food security and some of its proximate variables the total effects derived from institutions are more than that derived form development programs. This clearly suggests the critical role that institutions play in the generation and transmission of development impacts. Finally, besides its role in providing evidence for development synergies and institutional impacts, the numerical analysis impact transmission reported here also has a major policy role. The numerical analysis can be a basis for identifying the weak links within the impact transmission process, including the development, institutional, and impact variables involved in such weak links. The same analysis can also rank the variables in terms of the magnitude of their marginal impacts and intensity of their linkages within the system. Such information is valuable for targeting impact channels and prioritizing variables in development planning and implementation.

9. Conclusions and Policy Implications

This paper has argued that the impact synergies among development programs and the impact enhancing role of institutions, though well known, have neither been properly treated nor fully accounted for in actual development planning, implementation, and evaluation. This problem has far reaching implications, especially for *meta*-development goals such as MDGs, which require effective institutions and an integrated approach to development planning and implementation for their realization. It is demonstrated graphically how the ignorance of the impact synergies among past, ongoing, and planned programs leads to biased impact assessment and how an insufficient treatment of the impact enhancing role of institutions leads to substantial welfare loss. To help address these serious problems, this paper has presented one approach for developing an evaluation methodology and also illustrated it in the empirical context of the Kala Oya Basin in Sri Lanka, using stakeholder-based information. Although the illustration here has considered the linkages among water-related programs, the methodology is generalizable to deal with more general linkages not only among other development programs but also other projects or policies having a common or closely related development goal.

The analytics of the institution-impact framework shows both the specific point at which different institutions influence the impact generation and transmission process as well as the mechanics of impact synergies among the past, ongoing, and planned programs. The mathematical replica of this framework provides additional insights into the functional relations and sequential linkages among the development, institutional, and impact variables. Evaluation of these analytics, mechanics, and linkages are valuable can be a basis for development design and implementation, especially in the packaging and sequencing programs and in the identification and strengthening of pathways and institutional configurations with major impact potential. The regression results provide considerable insights into the specific roles that institutions play in the generation and transmission of impacts across impact pathways as well as the extent of impact synergies that development programs derive from each other. These development synergies are captured not only by the coefficients of the variables representing the development programs but also by those of the other impact and institutional variables. Since these coefficients are the statistical representation of the consensus prevalent among the selected stakeholders, their size, direction, and significance show the relative importance of the development, impact, and institutional variables included in the model. By unbundling the impact process and deciphering its transmission channels, the system model is also able to capture the flow and direction of development impacts as well as to show which institutions affect what channel. The sensitivity analysis performed with the reduced form equation has also shed light on the flow of development synergies and institutional impacts both at the layer-specific and system-wide contexts. All these are valuable information for policy design, institutional analysis, and impact assessment.

From a policy perspective, the main message is that when planning a new development program, project, or policy for a given region, it is crucial to take stock of the potential synergies possible from past, ongoing, and planned programs, projects, or policies with common or closely related goals. In our study region, for example, the implementation of system rehabilitation has had a substantial facilitating impact on the performance of bulk water distribution and this positive synergy has the potential to enhance the prospects for crop diversification. The results also indicate that the development synergies among the programs can be enhanced with a fine-tuning of the legal, policy, and organizational components of institutions related to the land, water, agriculture, market, and trade spheres. Although the institutions covered here are not exhaustive, the results do show that among the institutions considered, those operating in the production and marketing spheres are relatively more important in terms of their role in channeling the impacts to the ultimate goal of food security. Specifically, since food prices and farm income are the most dominant factors affecting food security, all their intermediary variables and their underlying institutions (e.g., markets, price regulation, land tenure, and credit and extension) are very important.

Besides the production-related farm institutions and distribution-related market institutions, there are also major influences from national level policies and laws such as those related to farm subsidy, rural industrialization, poverty alleviation, and wage rates and working conditions. But, at the same time, customary institutions related to cultivation practices and common grazing lands have significant effects on crop choice and livestock development. Notably, customary tendencies towards paddy cultivation, though a serious constraint for crop diversification, have a positive effect on the supply side of food security. To what extent changes in the performance of these rural institutions could affect the ultimate goal can be evaluated in terms of chain functions capturing how a marginal change in any of the institutions leads to a series changes within the equation systems and culminates finally in the marginal change in food security. Similarly, how impact synergies among development programs contribute to the final goal can also be evaluated in terms of the marginal changes in one or more of the variables characterizing various impact chains. Sensitivity analysis of this nature can provide valuable information for policy makers in prioritizing institutions and sequencing development programs.

From an overall perspective, the econometric property and theoretical consistency of the model results also suggest the proposed methodology of institution-impact interaction to be highly robust and the empirical approach of using perception-based information to be very reasonable. While the methodology and empirical approach are intuitive and the results provide considerable insights into the internal dynamics of and institutional roles in impact transmission, one cannot ignore the limitations of the present attempt and the scope for further refinements. Some of the limitations are obviously related to the specification and structuring of equations. The unexpected signs for and insignificance of crucial variables in some equations are also problems that can be avoided with a more refined specification of equations. Although only the perception-based qualitative data is used here to provide an empirical demonstration of evaluation approach, it is possible to explore ways for using observed and quantitative data from secondary sources and household surveys for as many variables as possible. In this case, a mix of quantitative and qualitative data can be used to estimate the model. More importantly, although the methodology can work well with a reasonable number of programs and impact pathways, it can become complicated when they are increased beyond a certain level. Despite these limitations, the paper is still able to develop and empirically illustrate an evaluation methodology that can deal with the issues of impact synergies and institutional roles in the practical contexts development planning, implementation, and impact assessment.

ENDNOTES

[1] Note that the development synergies can be both positive and negative, depending on the nature of the development programs considered together. These synergies relate only to the enhanced or reduced welfare effects of one program due to the externalities from the other programs. Thus, these synergies capture the difference between the sums of their individual impacts when implemented in isolation and their joint impacts when implemented and evaluated together.

[2] The MDGs, which came from the Millennium Declaration adopted in 2000 by all 189 UN member states, set targets for countries to reduce poverty, hunger, disease, illiteracy, and gender bias and improve environmental sustainability and global governance by 2015. These targets are now accepted by the international development and donor agencies as a framework for monitoring development progress (*http://www.un.org/millenniumgoals/index.html*).

[3] For instance, in the case of the food security impact of an irrigation project, one pathway can be characterized by the chain of variables, i.e., irrigation—productivity—food output—food availability—food prices—food security. Besides this output pathway, there is also an income pathway, i.e., irrigation—cropping intensity—employment—wages—income—food security. More such paths can also be visualized and constructed. Note that these paths enable us to incorporate also the role of relevant institutional variables (e.g., production, extension, input, and market institutions, price regulations, and trade and rural development policies). This is illustrated in Figure 5 (where the pathways are traced and depicted) and in the system model (where they are formally characterized as equations).

[4] For instance, a review of the available approaches, as presented and evaluated by Baker (2000), Bourguignon and de Silva (2003), and Center for Global Development (2006), suggests that their main application is with respect to an individual project, policy, or program, their evaluation confines to isolated impacts, and their focus is on the ultimate policy goal or few of their intermediaries.

[5] Of them, system rehabilitation was already implemented, but bulk water distribution is being implemented only on a pilot scale in the canal areas of the basin. Crop diversification, is only being planned, though the Government of Sri Lanka has a national policy to promote agricultural diversification.

[6] MAPP is a stakeholder-centred method involving an open approach and a seven-step procedure where the stakeholders are asked to award points on various aspects and criteria related to one or more development programs and their impacts on development goals. See Neubert (2000 and 2006) for a detailed description of this method.

[7] PSIA is a method for evaluating the distributional consequences of policy reforms on different groups in terms of the direct and indirect as well as the immediate and future impacts as transmitted through channels such as: prices and wages, employment, access to goods and services, assets, transfers and taxes, and authority. To account for the temporal differences and varying nature in the flow of reform impacts, the method combines secondary data and objective and perceptional data from a sample of intended beneficiaries/losers. See the Department of International Development and World Bank (2005) and Coudouel, Dani, and Paternostro (2006) for the description and application of this method.

[8] Although the PSIA is originally intended to be participatory, with an excessive focus on objective data and scientific quality, it has tended to become more technocratic (Coudouel, Dani, and Paternostro, 2006:12), making it unable to capture the valuable information

held by stakeholders—both beneficiaries as well as those involved in development research, planning, and implementation.

[9] A general application of this framework for a global ranking of institutional health and reform prospects within the water sector is illustrated in Dinar and Saleth (2005).

[10] For instance, in the case of water development program, we have included only five main paths, though, in reality, each of these paths will affect the development goals through several routes. For instance, the irrigation path will have different but related routes such as production route (i.e., irrigation-cropping intensity-productivity-food supply), income route (irrigation-productivity-employment-income), price routes (irrigation-production-food prices), resource routes (irrigation-waterlogging-salinity-land degradations), etc. Similar routes and the associated chain of variables can also be found for the other four impact paths.

[11] In the impact routes characterized by different chains of variables (see note 3), it is possible to include relevant institutional variables. For instance, production, input, and extension-related institutional variables can be added with the impact variables characterizing the production route. Similarly, institutional variables related to market, trade, and price regulation can be added with the impact variables underlying the price route. This will help us to formally and functionally capture the direct and interactive effects of the impact and institutional variables on the intermediary and final goals. We will see this more clearly in Section 5.

[12] These programs were actually selected from a list of 16 programs based on the priority points of the sample stakeholders. The list included both the completed, ongoing, and potentially relevant programs in the particular context of the study region.

[13] Note that some components of this environment (e.g., development policy, production relations, and institutional and macro policy aspects) are internalized within the flow chart. Although the effects of other such factors (e.g., climatic change and national and international political environment) are not considered in Figure 5, it is possible to evaluate them by comparing the institution-impact relations under different scenarios representing the status of these exogenous factors.

[14] The impact variables are actually the economic, technical, and physical variables that act as the ‘impact transmission variables’. They are not to be confused with those in the impact assessment literature, where ‘impact variables’ relate only to the ultimate end-goals (see Neubert, 2000). In the context of our framework, it is still appropriate to treat them as impact variables because (a) they do capture the intermediary impacts (or, outcomes) and (b) such impacts are specifically evaluated using equations representing different impact layers.

[15] Notice that the 17 impact variables also include the four variables, i.e., farm income, wage income, food availability, and food price, which are actually the intermediate goals linked immediately with the final goal of food security.

[16] Note that in the case of quantitative variables (e.g., productivity, income, employment, and food consumption, these scores can be easily converted into quantitative equivalents by using the range of minimum and maximum values observed in the study area. But, in the context of cross-sectional regression and when using with qualitative variables (e.g., the performance and effects of most institutional variables) where performance scores are indispensable, the results will not be qualitative different whether one uses the scores or their quantitative equivalent for the quantitative variables.

[17] The order condition requires that in the case of each equation, the number of excluded exogenous variables is greater than the number of included endogenous variables less one.

In simple terms, this condition ensures that there are enough exogenous variables excluded so that they can serve as instrumental variables for estimating the endogenous variable appearing as the dependent variable in each equation. The rank condition, though quite technical, requires, in simple terms, that all the equations are distinct in the sense that none of them can be formed with the linear combinations any other two equations in the system (see Kennedy, 1987: 138 & 142).

[18] Notably, these stakeholders are not the direct beneficiaries of the development programs. This is partly to avoid the potential bias and partly to address the macro-micro dichotomy evident in empirical impact evaluation literature, i.e., micro evaluations report considerable impact whereas macro evaluations find little or no impact, or *vice versa* (Neubert, 2000; Coudouel, Dani, and Paternostro, 2006).

[19] In view of the technical nature of the analytical framework and questions, the original plan was to have a sample of only government officials and researchers. However, we also tried to test whether the questionnaire can be administered to farmers and community leaders. This is how the three farmers and community leaders were added to the sample. As the experience shows that they are able to understand and answer the questions well, the present exercise can very well be repeated with a sample exclusively of farmers and local leaders.

[20] Note that instead of the simple average, it is also possible to use weighted average based on a principal component analysis. But, simple averages are used essentially to have a more balanced and unbiased values for the variables.

[21] To test for multicollinearity, a correlation analysis was performed for the 32 variables. The correlation matrix showed that only in four cases (SYSREHAB vs. BULKWATD and WATINSTN, RURALEMP vs. FEEDSUPLY, and AGLINCOM vs. FAMINCOM) did the correlation coefficient was over the threshold of $r>0.5$ (see Hair et al. 1995). Since none of them were used together as independent variables in any equation, the multicollinearity can be taken not as a serious problem.

[22] The result is somewhat surprising because the bulk water provision, as being piloted in the study region, is only to farmer groups and not to individual farmers as needed for promoting independent crop decisions.

[23] Note that the strong positive effect of CROPATEN on LABPRODY cannot be interpreted simply as food crops are more conducive for labor productivity. It needs to be explained in the light of the inverse relation between WAGERATE and RURALEMP seen in Equation [13], which means that high wage limits labor use and with a given farm productivity, lesser labor use causes labor productivity to be higher than otherwise. It is this effect occurring in the face of a labor scarcity and paddy domination that is behind the positive association seen between CROPATEN and LABPRODY.

[24] The inverse relation between RURALEMP and LIVSTOCK suggests the tradeoff in labor time allocation between wage employment and livestock rearing, which is particularly so among the groups which need both sources of income.

[25] It is important to note that even though bulk water delivery policy and water institution are part of institutions, they remain only endogenous because the former is specified as a function of system rehabilitation and the later is specified as a function of bulk water delivery policy.

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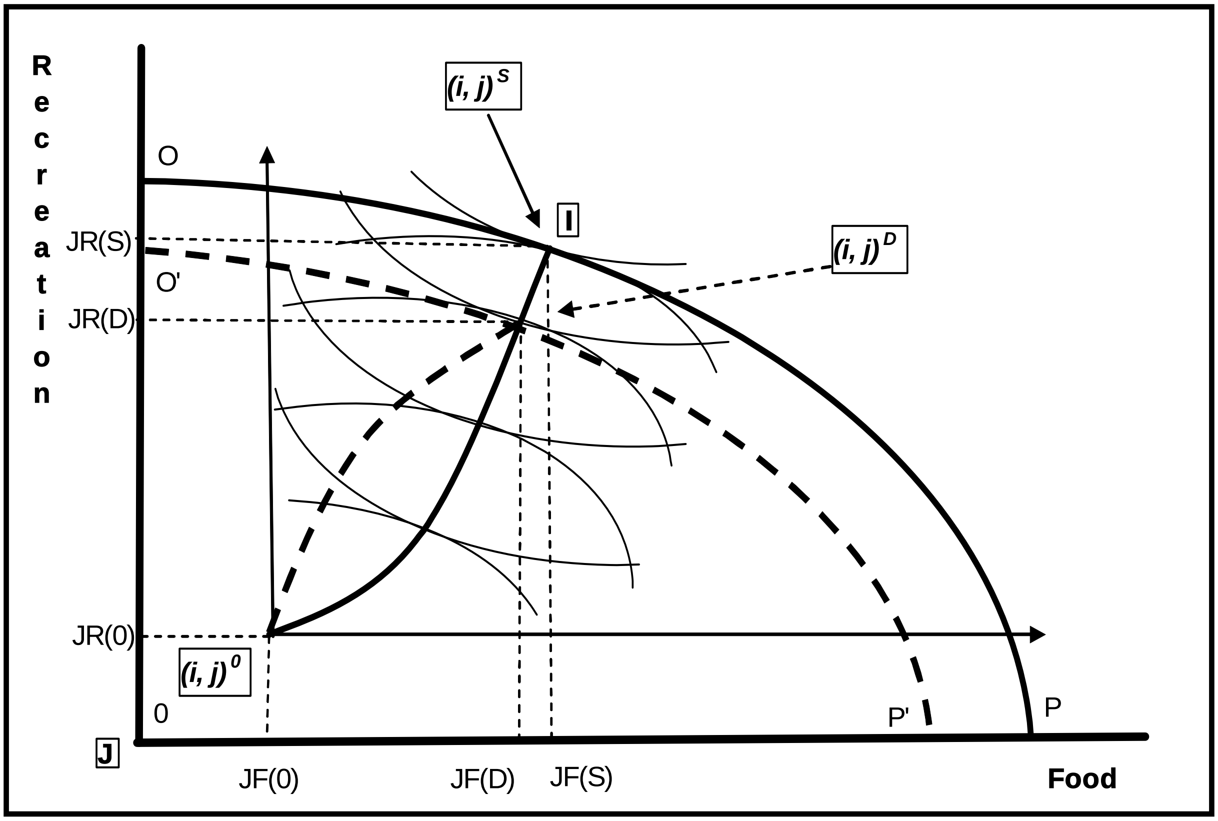

Figure 1: Ex-ante Evaluation of Alternative Programs and Social Welfare

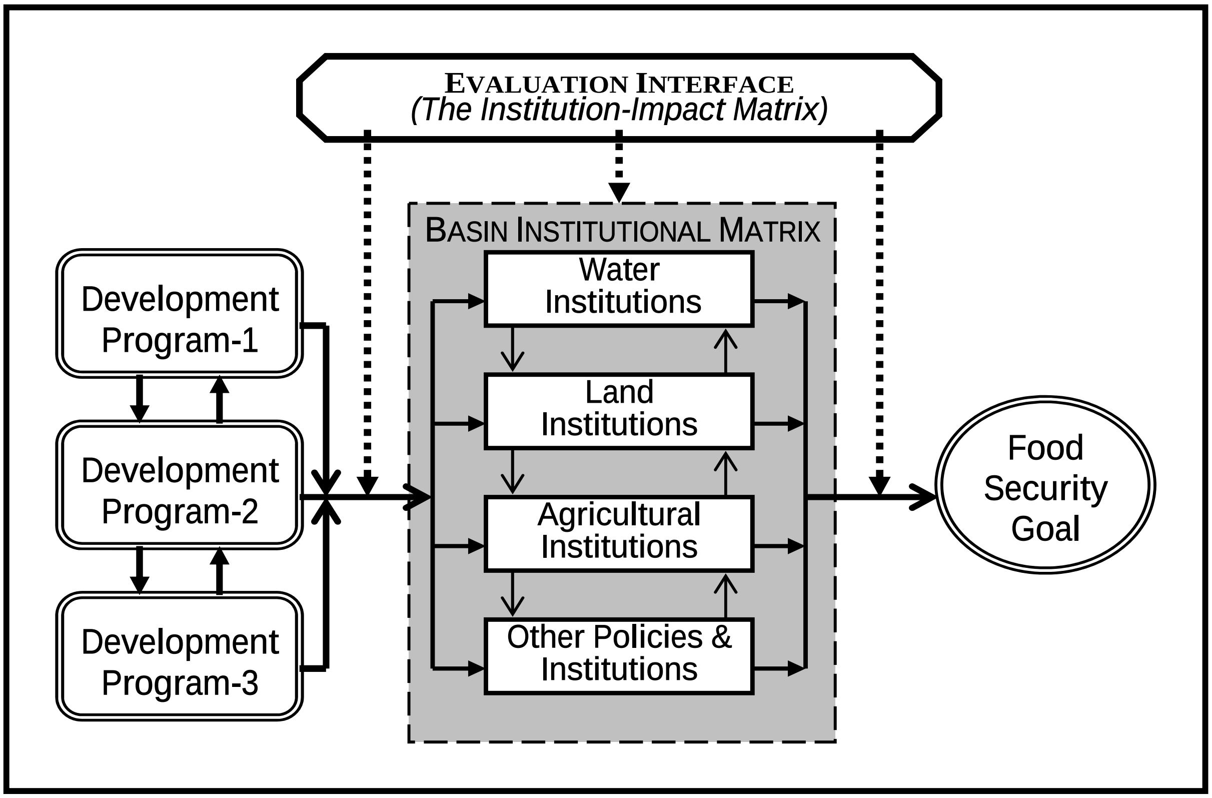

Figure 2: Conceptual Frame for Institution-impact Interface

Development Program 3 (Watershed Development)

Development Program 2 (Introduction of New Crop Varieties)

Development Program 1 (Water Development/Dam Construction)

Impact Pathways	Institutional Configurations *(Defined by combinations of variables capturing the land, water, agricultural, and resource/environment institutions)*				Development Goals *(In terms of variables capturing poverty, food and resource conservation goals)*		
	Water Institutions	Land Institutions	Agricultural Institutions	Res/Env Institutions	Income/ Jobs	Food Price/ Output	Efficient Use of Resources
Irrigation	Water rights/ User organs ($$$)	Land tenure/ Tenancy ($$$)	Input system/ extension ($$$)	Water/soil quality codes ($$$)	($$$)	($$$)	($$$)
Regional Growth	Basin institutions ($$$)	Land markets ($$$)	Farm wage policy ($$$)	Pollution regulations ($$$)	($$$)	($$$)	($$$)
Urbanization	Sectoral water Allocation ($$$)	Farmland use rules ($$$)	Rural-urban markets ($$$)	Wastewater regulations ($$$)	($$$)	($$$)	($$$)
Water Supply	Pricing & cost recovery ($$$)	Property ownership ($$$)	Wastewater use practice ($$$)	Sanitation Policy ($$$)	($$$)	($$$)	($$$)
Ecological Effects	Project choice & scale ($$$)	Policy on commons ($$$)	Policies on fragile areas ($$$)	Forest laws & policies ($$$)	($$$)	($$$)	($$$)

Note: $$$ = Values of actual or perception-based information on one or more variables designed to capture both the status and effectiveness of each of the institutional aspects as well as the level of impacts on each of the food security aspects.

Figure 3: Institution-impact Matrix: A Simplified Presentation

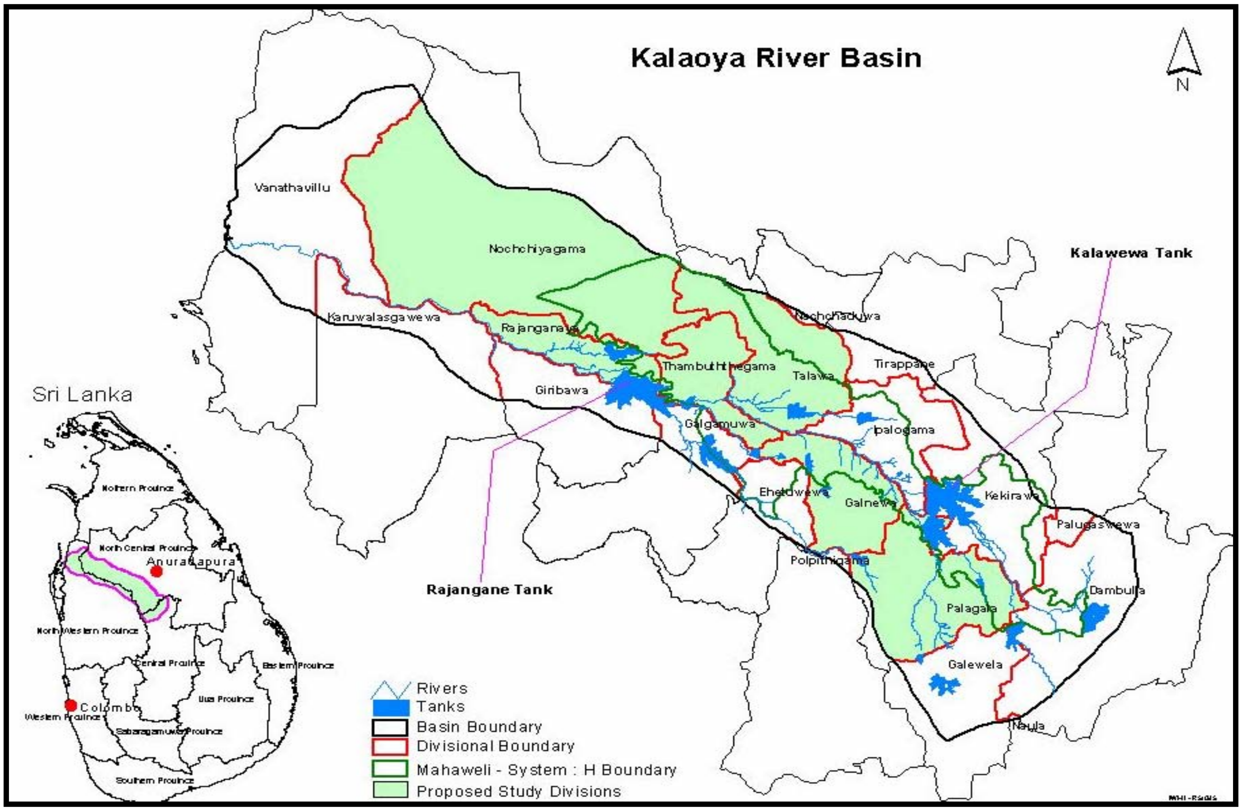

Figure 4: The Kala Oya Basin, Sri Lanka

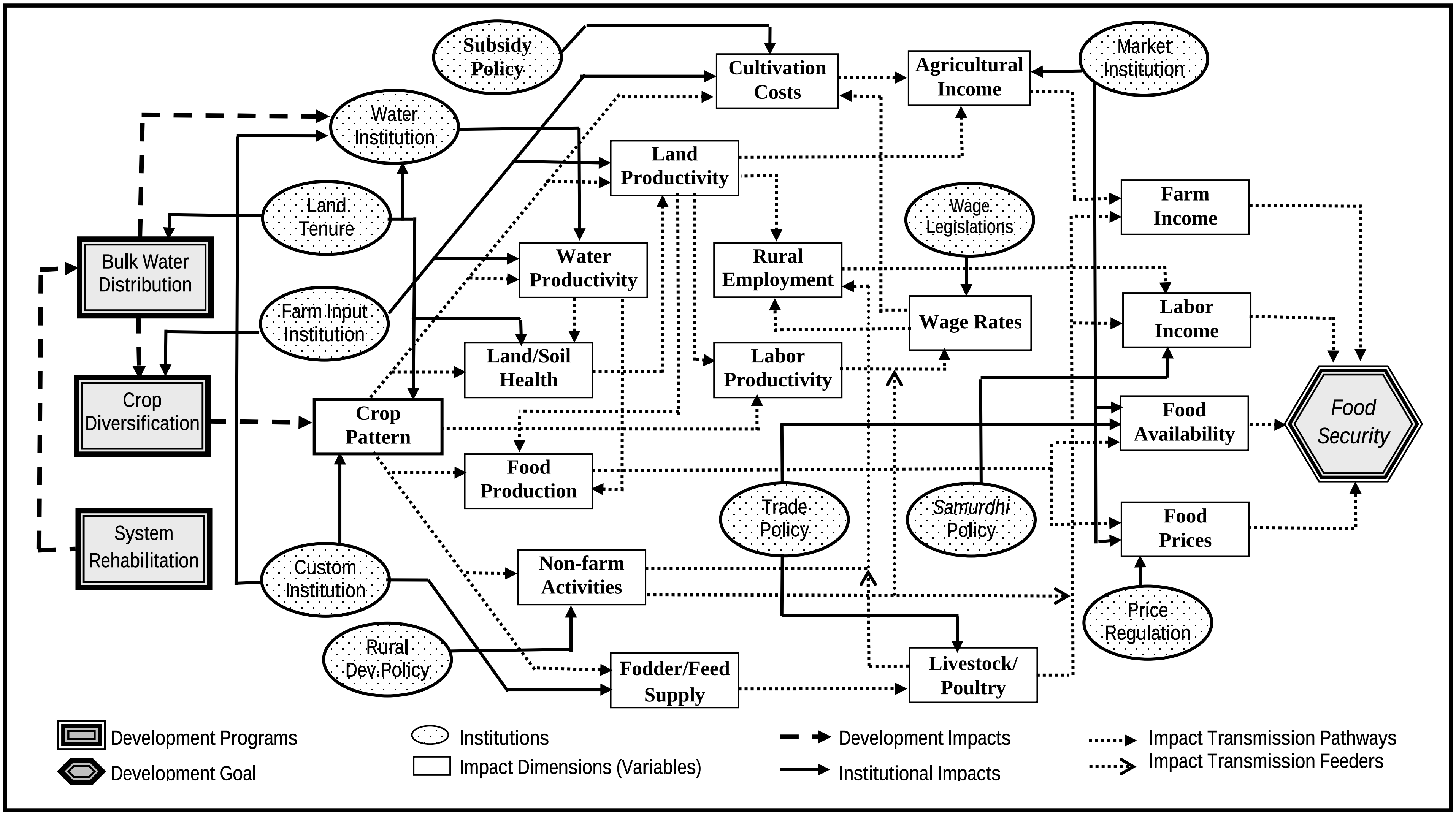

Figure 5: Institution-Impact Interactions with 3 Development Programs

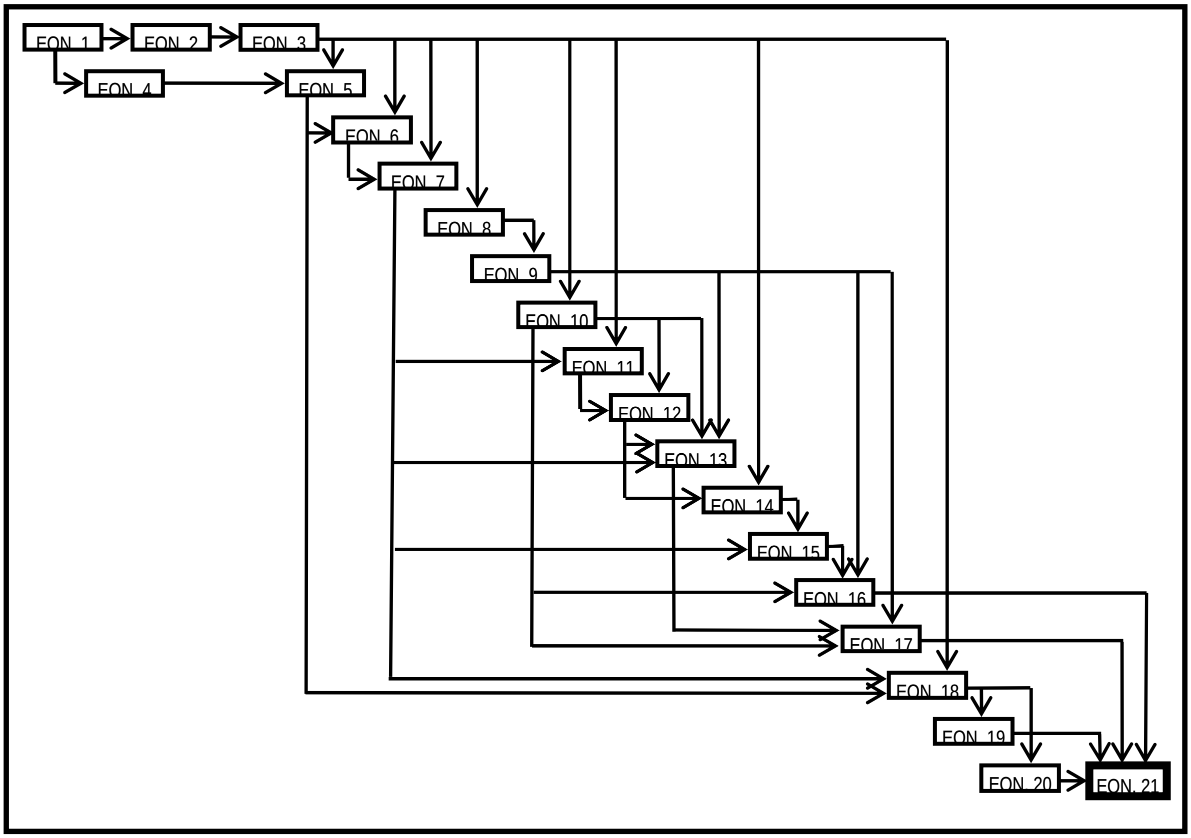

Figure 6: Structural Linkages within the Model

Table 1: Variables in the Institution-impact Model

Categories of Variables	No	Names of Variables	Acronym Used
Development Goal	1	Food Security	FOODSECT
Development Programs	1	System Rehabilitation	SYSREHAB
	2	Bulk Water Distribution	BULKWATD
	3	Crop Diversification	CROPDIVR
Impact Variables	1	Crop Pattern	CROPATEN
	2	Land Productivity	LANPRODY
	3	Water Productivity	WATPRODY
	4	Labor Productivity	LABPRODY
	5	Rural Employment	RURALEMP
	6	Wage Rates	WAGERATE
	7	Cultivation Costs	CULTCOST
	8	Agricultural Income	AGLINCOM
	9	Land Quality/soil Health	LANHELTH
	10	Food Production	FOODPROD
	11	Non-farm Enterprises	NFAMENTS
	12	Fodder & Feed Supply	FEDSUPLY
	13	Livestock/Poultry	LIVSTOCK
	14	Farm Income	FAMINCOM
	15	Labor Income	LABINCOM
	16	Food Availability	FOODAVAL
	17	Food Price	FOODPRIC
Institutional Variables	1	Land Tenure	LANTENUR
	2	Water Institutions	WATINSTN
	3	Customary Institutions	CUSINSTN
	4	Farm Input Institutions	FAMINSTN
	5	Market Institutions	MKTINSTN
	6	Price Regulations	PRICREGL
	7	Wage/Labor Legislations	WAGELAWS
	8	Rural Development Policy	RDVPOLCY
	9	Trade Policy	TRDPOLCY
	10	Farm Subsidy Policy	SUBPOLCY
	11	*Samurdhi* Policy	SAMPOLCY

Table 2: Descriptive Statistics for Model Variables

No	Endogenous Variables	Mean	Standard Deviation	Minimum	Maximum
1	BULKWATD	6.32	1.75	1.00	9.00
2	CROPDIVR	6.04	1.79	2.00	10.00
3	CROPATEN	5.60	1.00	2.79	7.57
4	WATINSTN	5.03	1.88	1.00	9.00
5	WATPRODY	7.29	1.42	4.00	10.00
6	LANHELTH	7.62	1.33	3.50	10.00
7	LANPRODY	6.84	1.40	2.63	10.00
8	FEDSUPLY	5.32	1.43	1.00	8.00
9	LIVSTOCK	3.64	1.62	0.90	7.90
10	NFAMENTS	7.07	1.29	2.25	9.50
11	LABPRODY	4.94	2.21	1.00	9.00
12	WAGERATE	6.10	1.27	2.50	8.50
13	RURALEMP	5.31	2.08	1.00	10.00
14	CULTCOST	5.66	1.68	1.00	8.00
15	AGLINCOM	6.90	1.49	3.00	10.00
16	FAMINCOM	5.50	1.09	3.00	9.00
17	LABINCOM	4.64	1.31	2.00	8.00
18	FOODPROD	5.22	1.23	2.33	7.67
19	FOODAVAL	5.24	1.36	2.50	8.50
20	FOODPRIC	4.37	1.31	1.50	7.50
21	FOODSECT	5.07	1.59	0.75	8.00
No	**Endogenous Variables**	**Mean**	**Standard Deviation**	**Minimum**	**Maximum**
1	SYSREHAB	6.75	1.19	1.67	8.83
2	LANTENUR	6.20	1.15	3.56	8.33
3	CUSINSTN	4.71	1.28	1.40	7.60
4	FAMINSTN	5.52	1.68	1.00	9.00
5	MKTINSTN	5.10	1.35	1.67	9.33
6	PRICREGL	4.62	1.57	1.00	8.75
7	WAGELAWS	3.51	1.74	1.00	8.50
8	RDVPOLCY	5.07	1.85	1.50	9.00
9	TRDPOLCY	6.57	1.41	3.00	9.00
10	SUBPOLCY	6.82	1.38	3.00	10.00
11	SAMPOLCY	5.12	1.97	1.00	10.00

Table 3: OLS Results for the Single Equation Model

Dependent Variable	Independent Variables	Estimated Coefficient	T-Ratio	Level of Significance	Elasticity at Means	R^2
FOODSECT	BULKWATD	0.317	***1.485***	0.146	0.395	0.447
	SYSREHAB	-0.053	-0.152	0.880	-0.070	
	CROPDIVR	-0.038	-0.251	0.803	-0.045	
	CROPATEN	-0.267	-0.652	0.519	-0.295	
	WATINSTN	0.255	***1.351***	0.185	0.253	
	WATPRODY	0.013	0.056	0.955	0.018	
	LANHELTH	-0.212	-0.864	0.393	-0.318	
	LANPRODY	-0.135	-0.459	0.649	-0.182	
	FEDSUPLY	0.124	0.554	0.583	0.130	
	LIVSTOCK	-0.111	-0.633	0.531	-0.080	
	NFAMENTS	0.057	0.258	0.798	0.080	
	LABPRODY	0.253	***1.606***	0.117	0.247	
	WAGERATE	0.506	**1.752**	0.088	0.610	
	RURALEMP	0.077	0.475	0.637	0.081	
	CULTCOST	0.125	0.715	0.479	0.140	
	AGLINCOM	-0.785	**-2.707**	0.010	-1.068	
	FAMINCOM	1.128	**2.910**	0.006	1.225	
	LABINCOM	0.452	***1.907***	0.065	0.414	
	FOODPROD	-0.118	-0.342	0.735	-0.122	
	FOODAVAL	0.125	0.487	0.629	0.129	
	FOODPRIC	-0.215	-0.898	0.375	-0.185	
	LANTENUR	-0.139	-0.613	0.544	-0.170	
	CUSINSTN	-0.102	-0.402	0.690	-0.095	
	FAMINSTN	-0.129	-0.618	0.540	-0.141	
	MKTINSTN	-0.253	-1.184	0.244	-0.255	
	PRICREGL	-0.003	-0.020	0.984	-0.003	
	WAGELAWS	-0.053	-0.256	0.800	-0.037	
	RDVPOLCY	0.107	0.634	0.530	0.108	
	TRDPOLCY	0.184	0.729	0.471	0.239	
	SUBPOLCY	-0.134	-0.720	0.476	-0.180	
	SAMPOLCY	0.173	0.876	0.387	0.175	

Table 4: System Model of Institution-Impact Interaction: 3-SLS Results

Eqn. No	Dependent Variables	Independent Variables	Estimated Coefficient	Asymptotic T-Ratio	Level of Significance	Elasticity at Means	R^2
[1]	BULKWATD	SYSREHAB	**0.886**	10.240	0.000	0.947	0.333
		LANTENUR	0.056	0.591	0.555	0.055	
[2]	CROPDIVR	BULKWATD	**0.594**	5.993	0.000	0.621	-0.366
		FAMINSTN	**0.385**	3.572	0.000	0.352	
[3]	CROPATEN	CROPDIVR	**0.438**	7.381	0.000	0.473	-0.354
		LANTENUR	**0.141**	1.897	0.058	0.156	
		CUSINSTN	**0.446**	7.107	0.000	0.375	
[4]	WATINSTN	BULKWATD	**0.851**	6.548	0.000	1.068	0.148
		LANTENUR	-0.014	-0.097	0.923	-0.017	
		CUSINSTN	-0.058	-0.465	0.642	-0.054	
[5]	WATPRODY	CROPATEN	**1.099**	8.446	0.000	0.845	-0.104
		WATINSTN	0.167	1.174	0.240	0.115	
		FAMINSTN	0.047	0.553	0.581	0.036	
[6]	LANHELTH	CROPATEN	**1.000**	4.747	0.000	0.736	-0.089
		WATPRODY	**0.358**	2.450	0.014	0.343	
		LANTENUR	-0.102	-0.800	0.424	-0.083	
[7]	LANPRODY	CROPATEN	**0.520**	2.323	0.020	0.425	0.285
		LANHELTH	**0.584**	4.039	0.000	0.650	
		FAMINSTN	-0.093	-1.515	0.130	-0.075	
[8]	FEDSUPLY	CROPATEN	**0.821**	7.167	0.000	0.864	-0.004
		CUSINSTN	0.152	1.160	0.246	0.134	
[9]	LIVSTOCK	FEDSUPLY	**0.613**	3.295	0.001	0.901	-0.686
		TRDPOLCY	0.028	0.192	0.847	0.052	
[10]	NFAMENTS	CROPATEN	**1.164**	20.910	0.000	0.922	-0.471
		RDVPOLCY	**0.107**	2.001	0.045	0.076	
[11]	LABPRODY	LANPRODY	-0.425	-1.230	0.219	-0.588	0.223
		CROPATEN	**1.413**	3.354	0.001	1.602	
[12]	WAGERATE	LABPRODY	0.138	1.158	0.247	0.111	-0.122
		NFAMENTS	**0.650**	8.605	0.000	0.753	
		WAGELAWS	**0.222**	2.969	0.003	0.128	
[13]	RURALEMP	LANPRODY	***0.671***	1.282	0.200	0.865	-0.120
		WAGERATE	-0.450	-1.474	0.141	-0.517	
		NFAMENTS	**0.752**	1.847	0.065	1.001	
		LIVSTOCK	**-0.515**	-2.931	0.003	-0.351	
[14]	CULTCOST	CROPATEN	-0.066	-0.134	0.893	-0.065	-0.337
		WAGERATE	**1.048**	1.905	0.057	1.130	
		FAMINSTN	-0.017	-0.105	0.916	-0.017	
		SUBPOLCY	-0.045	-0.312	0.755	-0.054	

Table 4 (Continued)

Eqn No	Dependent Variables	Independent Variables	Estimated Coefficient	Asymptotic T-Ratio	Level of Significance	Elasticity at Means	R^2
[15]	AGLINCOM	LANPRODY	**0.609**	3.963	0.000	0.605	0.030
		CULTCOST	**0.394**	2.909	0.004	0.323	
		MKTINSTN	0.097	0.950	0.342	0.072	
[16]	FAMINCOM	AGLINCOM	0.136	1.131	0.258	0.170	0.116
		NFAMENTS	**0.437**	3.773	0.000	0.561	
		LIVSTOCK	**0.412**	6.153	0.000	0.271	
[17]	LABINCOM	RURALEMP	**-0.437**	-2.545	0.011	-0.501	-0.649
		NFAMENTS	**0.550**	2.560	0.010	0.839	
		LIVSTOCK	**0.778**	5.153	0.000	0.608	
		SAMPOLCY	0.061	0.758	0.449	0.067	
[18]	FOODPROD	CROPATEN	**0.823**	5.501	0.000	0.883	0.400
		LANPRODY	**0.312**	1.949	0.051	0.409	
		WATPRODY	**-0.206**	-2.115	0.034	-0.287	
[19]	FOODAVAL	FOODPROD	**0.451**	2.816	0.005	0.449	0.149
		TRDPOLCY	**0.319**	3.629	0.000	0.400	
		MKTINSTN	0.160	1.426	0.154	0.156	
[20]	FOODPRIC	FOODPROD	**0.474**	4.329	0.000	0.566	0.096
		PRICREGL	**0.131**	1.812	0.070	0.139	
		MKTINSTN	**0.257**	2.504	0.012	0.300	
[21]	FOODSECT	FOODAVAL	**0.520**	2.280	0.023	0.538	-0.670
		FOODPRIC	**-0.965**	-2.932	0.003	-0.833	
		FAMINCOM	0.767	1.603	0.109	0.833	
		LABINCOM	0.507	1.622	0.105	0.465	
Sample Size							67
Endogenous Variables							21
Exogenous Variables							11
System R^2							0.878
Chi-Square (with 61 degrees of freedom, P=0.000)							140.9

<u>Notes</u>: (a) This model is estimated with no constant term in all equations.

(b) Bold coefficients are significant at 10 percent or better.

(c) Elasticity at means are the weighted coefficients with the weights being the ratio of the means of the concerned dependent and independent variables, This standardization enables a comparison of the relative importance of the independent variables both within and across equations.

(d) Unlike OLS, where R^2 has the range of 0-1, the R^2 in the case of 3-SLS can range from $-\infty$ to 1. The relevant statistics to be considered in the case of 3-SLS estimation are the System R^2, which captures the explanatory power of the model as a whole and Chi-Square, which constitutes a test of the overall significance of the model.

Table 5: Size and Flow of Development Impacts and Synergies

Endogenous Variables	Equation Numbers	Development Programs			Total Effects Received
		System Rehabilitation	Bulk Water Delivery	Crop Diversification	
BULKWATD	***y1***	0.886	-	-	0.886
CROPDIVR	***y2***	0.526	0.594	-	1.120
CROPATEN	***y3***	0.231	0.261	0.438	0.930
WATINSTN	***y4***	0.754	0.851	-	1.605
WATPRODY	***y5***	0.379	0.427	0.481	1.287
LANHELTH	***y6***	0.366	0.346	0.172	0.884
LANPRODY	***y7***	0.334	1.289	0.583	2.206
FEDSUPLY	***y8***	0.189	0.213	0.395	0.797
LIVSTOCK	***y9***	0.116	0.130	0.220	0.466
NFAMENTS	***y10***	0.268	0.302	0.509	1.079
LABPRODY	***y11***	0.374	0.035	0.522	0.931
WAGERATE	***y12***	0.280	0.310	0.484	1.074
RURALEMP	***y13***	0.229	0.261	0.426	0.916
CULTCOST	***y14***	0.278	0.417	0.655	1.350
AGLINCOM	***y15***	0.313	0.106	0.166	0.585
FAMINCOM	***y16***	0.262	0.081	0.137	0.480
LABINCOM	***y17***	0.275	0.782	0.249	1.306
FOODPROD	***y18***	0.239	0.296	0.390	0.925
FOODAVAL	***y19***	0.108	0.133	0.176	0.417
FOODPRIC	***y20***	0.113	0.140	0.185	0.438
FOODSECT	***y21***	0.011	0.226	0.395	0.632
Total Effects Generated		6.531	7.200	6.583	20.314

Table 6: Size and Flow of Institutional Impacts

Endogenous Variables	Equation Number	Institutional Variables										Total Effect Received
		LANTENUR	CUSINSTN	FAMINSTN	MKTINSTN	PRICREGL	WAGELAWS	RDVPOLCY	TRDPOLCY	SUBPOLCY	SAMPOLCY	
BULKWATD	*y1*	0.056	-	-	-	-	-	-	-	-	-	0.056
CROPDIVR	*y2*	0.033	0.385	-	-	-	-	-	-	-	-	0.418
CROPATEN	*y3*	0.156	0.446	0.169	-	-	-	-	-	-	-	0.771
WATINSTN	*y4*	0.034	-0.058	-	-	-	-	-	-	-	-	-0.024
WATPRODY	*y5*	0.177	0.481	0.232	-	-	-	-	-	-	-	0.890
LANHELTH	*y6*	0.117	0.618	0.252	-	-	-	-	-	-	-	0.987
LANPRODY	*y7*	0.149	0.593	0.142	-	-	-	-	-	-	-	0.884
FEDSUPLY	*y8*	0.128	0.518	0.139	-	-	-	-	-	-	-	0.785
LIVSTOCK	*y9*	0.078	0.318	0.085	-	-	-		0.028	-	-	0.509
NFAMENTS	*y10*	0.181	0.519	0.196	-	-	-	0.107	-	-	-	1.003
LABPRODY	*y11*	0.145	0.648	0.129	-	-	-	-	-	-	-	0.922
WAGERATE	*y12*	0.119	0.493	0.111	-	-	0.222	0.015	-	-	-	0.960
RURALEMP	*y13*	0.140	0.391	0.148	-	-	-0.114	0.073	-0.013	-	-	0.879
CULTCOST	*y14*	0.114	0.487	0.088	-	-	0.233	0.016	-	-0.045	-	0.427
AGLINCOM	*y15*	0.136	0.553	0.121	0.097	-	0.092	0.006	-	-0.018	-	0.987
FAMINCOM	*y16*	0.146	0.498	0.147	0.040	-	0.038	0.049	0.004	-0.007	-	0.915
LABINCOM	*y17*	0.174	0.451	0.186	-	-	-0.089	0.116	-0.022	-	0.061	0.877
FOODPROD	*y18*	0.152	0.395	0.182	-	-	-	-	-	-	-	0.729
FOODAVAL	*y19*	0.069	0.178	0.082	0.319	-	-	-	0.160	-	-	0.808
FOODPRIC	*y20*	0.072	0.187	0.086	0.131	0.257	-	-	-	-	-	0.733
FOODSECT	*y21*	-0.003	0.055	0.004	0.332	0.130	0.106	-0.086	0.146	-0.004	0.059	0.739
Total Effects Generated		2.373	8.156	2.499	0.919	0.387	0.250	0.296	0.329	-0.074	0.120	15.255

ANNEX A: TECHNICAL NOTES

***Institutional Ecology Principle*:** This principle extends the 'ecosystem' concept to institutional systems to analytically show (a) the linkages and synergies among institutions across domains (law, policy, and organization), spheres (land, water, agricultural, rural, and environmental), and scales (basin, region, and national) and (b) the nested and embedded character of institutions within the social, economic, political, and resource systems.

***Institutional Decomposition and Analysis Framework*:** This framework unbundles institutions into a set of interrelated rules, characterizes them using quantitative and qualitative variables, and formalizes the relations and linkages among these rules (Saleth and Dinar, 2004). The approach is similar in spirit to the Institutional Analysis and Development framework developed by Ostrom (1990) for application to local level institutions for common pool resources management.

***Ex-ante Approach*:** This approach tries to evaluate the futuristic changes and expectation aspects related to institutions based on the convergence in stakeholders' perception. Such consensual perception can summarize objective evaluation, learned judgments, aspirations, and expectations of participating stakeholders. Unlike the *post mortem* approach underlying the *ex-post* evaluation and analysis, the *ex-ante* approach is very useful for designing anticipatory and coping strategies that would allow enough lead time for policy/program adjustments and modifications.

***Adaptive Instrumental Evaluation*:** Unlike other evaluation approaches in economics relying on normative and absolute concepts such as 'efficiency' based on the assumption of individual rationality and perfect information, the adaptive instrumental evaluation is based on a positive and relative approach (Tool, 1977; Kahneman and Tversky, 1984; Bromley, 1985). It allows the evaluation of events/aspects with respect to relevant reference points (e.g., best practices, desirable conditions, and stated objectives) rather than with respect to ideals or absolute conditions. It also allows the reference points to be flexible and changeable within the evaluation process itself (Saleth and Dinar, 2004). This approach is very pertinent for evaluating aspects such as institutions and their performance involving considerable level of qualitative and subjective considerations.

ANNEX B: SURVEY INSTRUMENT

"THE INSTITUTIONAL MATRIX OF THE MILLENNIUM DEVELOPMENT GOALS: AN EMPIRICAL STUDY OF FOOD SECURITY GOALS IN KALA OYA BASIN, SRI LANKA"

(Research Preparation Work funded by WB and IWMI)

PART-A: INSTRTUCTIONS

(1) The conceptual framework is generic, but captures as much as possible the relevant aspects of KOB basin in particular and Sri Lanka in general;

(2) It is focused on the impact of the three development programs on food security, particularly from the perspective of small farmers, farm workers, and other rural poor;

(3) 'Impact pathways' are the routes through the economic impacts of development programs are transmitted to the development goals. These impact transmissions are carried out by the 'impact variables'. In the present context, three development programs (i.e., crop diversification program; system rehabilitation, and bulk water allocation policy) and one development goal (i.e., food security) are considered.

(4) Before asking questions, the conceptual framework is briefly explained to give adequate background for the respondents. First, the 3 development programs and their role in food security, then, their impact pathways defined by the impact variables, and, finally, the role of institutional factors in affecting these pathways are all explained to them.

(5) The respondents are also informed that the questions to be asked are related to different components of the framework and answers are expected with respect to the conditions prevalent in KOB in particular and Sri Lanka in general.

(6) More importantly, it is necessary to convince them that the evaluation is done in an ex-ante context and what they perceive or believe about various relationships in the conceptual framework are very important and valuable for the evaluation and analysis. Also, it is important to inform them that the development programs can both those that are implemented as well as those that are contemplated or potentially relevant for the KOB or Sri Lanka.

(7) All questions are formulated as yes or no questions or questions requiring answers within the scale of 1-10, with '1' being low or weak and '10' being high or strong, depending on the context. For coding purpose, a 'no' answer is treated as 0 and the 'yes' answer is evaluated within the scale of 1-10. Thus, all answers are recorded within the scale of 0-10.

PART-B: BASIC DETAILS

(1) Respondent's Details:

(a) Name ……………………………………….

(b) Qualification ……………………………………….

(c) Discipline ……………………………………….

(d) Professional Position ……………………………………….

(e) Years of Experience ……………………………………….

(f) Contact Details ……………………………………….

……………………………………….

……………………………………….

……………………………………….

Email……………………………………

(2) Interview Details:

(a) Interviewers Name ……………………………………

(b) Place and Date ……………………………………

PART–C: QUESTIONNAIRE

1. Food Security (FOODSECT)

(a) How strong, in your opinion, is the food security status of small farmers?.. ☐

(b) How strong, in your opinion, is the food security status of farm workers? .... ☐

(c) How strong, in your opinion, is the food security status of the rural poor? .... ☐

(d) How strong, in your opinion, is the nutritional status of children and aged? .... ☐

2. Crop Diversification (CROPDIVR)
(From low to high-value crops; e.g., paddy to vegetables, oilseeds, and fruits)

(a) How bright are the economic and technical prospects for crop diversification? .... ☐

(b) How effective are the crop diversification efforts of the government? .... ☐

(c) How important are customs in crop choice? .... ☐

(d) How serious are customs in constraining crop diversification? .... ☐

(e) How important is water delivery system for crop diversification? .... ☐

(f) How serious is small farm size as a constraint for crop diversification? .... ☐

(g) How important is land and soil quality as a factor for crop diversification? .... ☐

3. System Rehabilitation (SYSREHAB)

(a) How effective is the system rehabilitation program? ....

(b) How far can rehabilitation improve land and soil health (by limiting salinity)? ....

(c) How important is system rehabilitation as a contributing factor for land productivity? ....

(d) How far system rehabilitation is effective in facilitating bulk water allocation? ....

4. Bulk Water Distribution (BULKWATD)

(a) How far can bulk water distribution improve existing water allocation procedures? ....

(b) How far can bulk water distribution strengthen water user organizations? ....

(c) How far can bulk water distribution contribute to crop diversification? ....

(d) How far can bulk water distribution improve water use efficiency? ....

(e) How far can bulk water distribution contribute to land & soil health? ....

5. Crop Pattern (CROPATEN)

(a) To what extent can crop diversification alter crop pattern? ....

(b) How far can diversification lead to the adoption of high-value crops? ....

(c) How far can the changes in crop pattern lead to water savings? ....

(d) Haw far can the changes in crop pattern improve land and soil health (via crop rotation)? ....

(e) How far can the changes in crop pattern negatively affect foodgrain output? ....

(f) How far can the changes crop pattern negatively affect fodder/feed supply? ....

(g) How far can the changes in crop pattern raise cultivation costs? ....

(h) If crop pattern shifts towards high-value crops, how important is this shift for the development of rural non-farm activities? ....

6. Land Productivity (LANPRODY)
(Output per unit of land; it differs by crops)

(a) How important is land productivity for farm employment? ....

(b) How important is land productivity for farm income? ....

(c) How important is land productivity for labor productivity? ....

(d) Generally, higher land productivity leads to higher water productivity. How strong will be this relationship between land and water productivity? ....

(e) Crop pattern changes, though reduce the area under food crops, can also improve the overall farm productivity. If so, how significant will be this effect? ....

(f) System rehabilitation and bulk water delivery can improve water delivery and contribute, thereby, to overall farm land productivity. If so, how significant will be this effect? ....

7. Water Productivity (WATPRODY)
(Output per unit of applied water; it differs by crops)

Generally, efficient water use contributes to land productivity, partly by minimizing the negative effects of water over use (e.g., waterlogging; Salinity) and partly by enhancing the efficiency and productivity of other farm inputs. If this is so,

(a) How strong will be the impact of water use efficiency on land productivity? .... ☐

(b) How strong will be the impact of water use efficiency on the efficiency of other inputs? .... ☐

8. Labor Productivity (LABPRODY)
(Output per labor; it differs by crops)

(a) Generally, higher labor productivity will lead to higher wage rate. If so, how strong (or weak) is the relationship between labor productivity and wage rates? .... ☐

(b) Generally, efficient and productive workers do the same or more work. If so, how important is the role of productivity in determining the overall level of farm employment? .... ☐

9. Rural Employment (RURALEMP)

(a) Generally, given the level of land productivity, more employment means less labor productivity. If so, how strong is this negative relationship? .... ☐

(b) Generally, for given wage rates, more employment means more income. But, with low or declining wage rates, more employment may not always lead to more income. How realistic is this fact? .... ☐

10. Wage Rates (WAGERATE)

(a) How strong is the influence of higher wage rates on cultivation costs? .... ☐

(b) Are the wage rates high enough to provide incentive for improved labor productivity? If so, how strong will be this effect? .... ☐

(c) Are the wage rates adequate enough to assure decent income for farm workers? If so, how strong will be this fact? .... ☐

11. Cultivation Costs (CULTCOST)

(a) Given that higher cultivation costs reduce agricultural income, will the additional costs due to crop diversification reduce small farmers' income?. If so, how serious is this cost effect on farm income? ... ☐

(b) At the same time, the additional costs due to diversification can also be smaller in relation to the additional income from the same. If so, how important is this fact for crop choice? .... ☐

12. Agricultural Income (AGLINCOM)

(a) While farm income is a necessary condition for food security, other non-income factors (e.g., food price and supply, its quality and composition, and family size) are also important. Given this, how important is the relative role of income in ensuring food security? .... ☐

13. Land Quality and Soil Health (LANHELTH)

(a) How important is land and soil health for land productivity, especially in the long-run? .... ☐

(b) How important is the land and soil health for flexible crop choice? .... ☐

14. Food Production (FOODPROD)

(a) Normally, higher food production means more food supply in the market. But, export, procurement, and hoarding can reduce food availability. If so, how serious is this effect? ....

(b) Similarly, higher food output means low food prices for consumers. But, the factors noted above may act against such price decline. If so, how serious is this effect? ....

15. Non-farm Enterprises (NFAMENTS)
(e.g., small enterprises, petty trade, handicrafts, services)

(a) Does labor scarcity affect farm wage rates? If so, how significant is this effect? ....

(b) How important are non-farm activities for rural employment? ....

(c) Do non-farm activities create farm labor scarcity? If so how serious is this effect? ....

16. Fodder and Feed Supply (FEDSUPLY)
(e.g., rice straw, husks, and other farm by-products)

(a) How important is the role of agriculture in supplying fodder and feeds? ....

(b) Does change in crop pattern (say from paddy to vegetables or oilseeds) will affect fodder supply? If so, how serious will be this negative effect? ....

(c) If the farm families with livestock rely on green fodder from public grazing lands and home gardens, crop pattern changes does not matter much. How realistic is this fact? ....

17. Livestock and Poultry (LIVSTOCK)
(This does not relate to commercial enterprises, but only maintained by rural families)

(a) How important are livestock & poultry for self-employment? ....

(b) How important are livestock & poultry as an income source for small farmers? ....

(c) How important are livestock & poultry as an income source for farm workers and the poor? ....

(d) How important are livestock & poultry for the family consumption of milk & meat? ....

(e) How important are livestock & poultry for the nutritional security of the children and aged? ....

18. Farm Income (FAMINCOM)

(a) How food-secure are the small farmers? ....

(b) Is this security due to their cultivating food (paddy) crops? If so, how realistic is this fact? ....

(c) Is food security role crops at the cost of crop diversification? If so, how realistic is this fact? ....

19. Labor Income (LABINCOM)

(a) How adequate are the wage income of rural workers to assure their food security? ....

(b) How critical are the livestock and non-farm income sources for rural workers and the poor? ....

20. Food Availability (FOODAVAL)

(a) How adequate is food availability to assure food security for rural workers and the poor? ....

21. Food Price (FOODPRIC)

(b) How affordable are food prices to rural workers and the poor? .... ☐

22. Land Tenure (LANTENUR)
(Farm size; Tenure Security)

(a) How important is farm size for adopting improved farm technologies and practices? .... ☐

(b) How important is tenure security for adopting improved farm technologies and practices? .... ☐

(c) How important is land titles in securing farm credits? .... ☐

(d) How serious are small farms as constraints for efficient water delivery?... ☐

(e) Are smaller farms more efficient in water use? If so, how realistic is this fact? .... ☐

(f) Generally, small farms are unable to benefit from scale economies.
If so, how serious is this fact in affecting their cultivation costs? .... ☐

23. Water Institutions (WATINSTN)
(Water release policy; allocation procedures)

(a) How flexible is the water release policy for promoting diverse crops? .... ☐

(b) How suitable are the existing water allocation practices for efficient water use? .... ☐

24. Farm Input Institutions (FAMINSTN)
(Credit, farm inputs, and extension institutions)

(a) How effective and accessible is the farm credit system for small farmers? .... ☐

(b) How effective and accessible are the fertilizer and seeds supply systems for small farmers? .... ☐

(c) How effective and accessible is the farm extension system for small farmers? .... ☐

(d) Are the farm input supply systems, including credit, too costly for small farmers?
If so, how serious is this issue? .... ☐

(e) Are the farm input supply, including credit, focused on particular crops (e.g., paddy or coconut)?
If so, how serious is this as a constraint for crop diversification? .... ☐

25. Customary Institutions (CUSINSTN)
(Local customs, conventions, traditions, and informal rules)

(a) Normally, farmers' choice of food or traditional crops (e.g., paddy) is thought to be influenced by
customary practices. If so, how limiting are local customs for crop diversification? .... ☐

(b) How influential are local customs and conventions in water allocation and use decisions? .... ☐

(c) Are there strong traditions in maintaining local commons as grazing areas for livestock? .... ☐

26. Rural Development Policy (RDVPOLCY)

(a) How effective are state policies in promoting rural non-farm activities? .... ☐

(b) Are there special programs for developing specific non-farm enterprises (e.g., handicrafts; food
processing units)? If so, how effective are they? .... ☐

27. Market Institutions (MKTINSTN)

(a) How effective are the agricultural markets in providing the right prices for farmers? .... ☐

(b) How important is the role of traders and middlemen in the marketing of farm outputs? .... ☐

(c) How effective are markets in stabilizing harvest and post-harvest price fluctuations? .... ☐

(d) How effective is the procurement policy in supporting farm prices? .... ☐

28. Wage/Labor Legislations (WAGELAWS)
(Legislations on wage rates and working conditions)

(a) How effective are the minimum wage legislations in guiding rural wage rates? .... ☐

(b) How strong are local customs and social pressures in influencing rural wage rates? .... ☐

(c) How effective are the special legal provisions (e.g., child labor; minimum working hour) in affecting rural labor supply and employment? .... ☐

29. Trade Policy (TRDPOLCY)
(Farm import and export policies)

(a) Do the trade policies on the import of milk and meat products limit livestock & poultry development? If so, how serious is this constraint? .... ☐

(b) Do the trade policies on the import of food products add to domestic food availability? If so, how important is this policy for food and nutritional security? .... ☐

30. Price Regulations (PRICREGL)

(a) How effective are price regulations in controlling the food prices for consumers? .... ☐

(b) Do price regulations distort agricultural markers? If so, how serious is this effect? .... ☐

31. Farm Subsidy Policy (SUBPOLCY)
(Fertilizer and credit subsidies)

(a) How effective are the subsidies for fertilizers and farm credits in reducing cultivations costs? .... ☐

(b) Do these subsidies have a favorable effect on farm income? If so, how significant are their effect? .... ☐

32. *Samurdhi* Policy (SAMPOLCY)
(Special State program for Poverty alleviation)

(a) How effective is the ***Samurdhi*** policy in supporting the income of the rural poor? .... ☐

(b) How effective is the ***Samurdhi*** policy in improving the food availability to rural poor? .... ☐

ANNEX C: DERIVING THE REDUCED FORM EQUATION

No	*Exogenous Variables*	*Notation used*
1	SYSREHAB	X1
2	LANTENUR	X2
3	CUSINSTN	X3
4	FAMINSTN	X4
5	MKTINSTN	X5
6	PRICREGL	X6
7	WAGELAWS	X7
8	RDVPOLCY	X8
9	TRDPOLCY	X9
10	SUBPOLCY	X10
11	SUMPOLCY	X11
No	*Endogenous Variables*	*Notation used*
1	BULKWATD	Y1
2	CROPDIVR	Y2
3	CROPATEN	Y3
4	WATINSTN	Y4
5	WATPRODY	Y5
6	LANHELTH	Y6
7	LANPRODY	Y7
8	FEDSUPLY	Y8
9	LIVSTOCK	Y9
10	NFAMENTS	Y10
11	LABPRODY	Y11
12	WAGERATE	Y12
13	RURALEMP	Y13
14	CULTCOST	Y14
15	AGLINCOM	Y15
16	FAMINCOM	Y16
17	LABINCOM	Y17
18	FOODPROD	Y18
19	FOODAVAL	Y19
20	FOODPRIC	Y20
21	FOODSECT	Y21

With the notations for all the exogenous and endogenous variables as assigned in the above table, the 21 equations of the system model can be represented as follows:

$$Y_1 = F_1(X_1, X_2)$$
$$Y_2 = F_2(Y_1, X_4)$$
$$Y_3 = F_3(Y_2, X_2, X_3)$$
$$Y_4 = F_4(Y_1, X_2, X_3)$$
$$Y_5 = F_5(Y_3, Y_4, X_4)$$
$$Y_6 = F_6(Y_3, Y_5, X_2)$$
$$Y_7 = F_7(Y_3, Y_6, X_4)$$
$$Y_8 = F_8(Y_3, X_3)$$
$$Y_9 = F_9(Y_8, X_9)$$
$$Y_{10} = F_{10}(Y_3, X_8)$$
$$Y_{11} = F_{11}(Y_3, Y_7)$$
$$Y_{12} = F_{12}(Y_{10}, Y_{11}, X_7)$$
$$Y_{13} = F_{13}(Y_7, Y_9, Y_{10}, Y_{12})$$
$$Y_{14} = F_{14}(Y_3, Y_{12}, X_4, X_{10})$$
$$Y_{15} = F_{15}(Y_7, Y_{14}, X_5)$$
$$Y_{16} = F_{16}(Y_9, Y_{10}, Y_{15})$$
$$Y_{17} = F_{17}(Y_9, Y_{10}, Y_{13}, X_{11})$$
$$Y_{18} = F_{18}(Y_3, Y_5, Y_7)$$
$$Y_{19} = F_{19}(Y_{18}, X_5, X_9)$$
$$Y_{20} = F_{20}(Y_{18}, X_5, X_6)$$
$$Y_{21} = F_{21}(Y_{16}, Y_{17}, Y_{19}, Y_{20})$$

Given these equations and their sequential linkages depicted in Figure 6, the reduced form equation can be specified as a single but very long equation shown below.

$$
\begin{aligned}
Y_{21} = F_{21}\oint\ & F_{20}\int \Big\| F_{18}\Big| F_7\Big\langle F_6\Big\{ F_5\Big[F_4\{F_1[X_1,X_2],X_2,X_3\},\\
& F_3\{F_2[F_1(X_1,X_2),X_4],X_2,X_3\},X_4 \Big],\\
& F_3\Big[F_2[F_1(X_1,X_2),X_4],X_2,X_3 \Big],X_2 \Big\},F_3\Big\{ F_2[F_1(X_1,X_2),X_4],X_2,X_3 \Big\},X_4 \Big\rangle,\\
& F_5\Big\langle F_4\{F_1[X_1,X_2],X_2,X_3\},F_3\{F_2[F_1(X_1,X_2),X_4],X_2,X_3\},X_4 \Big\rangle,\\
& F_3\Big\langle F_2[F_1(X_1,X_2),X_4],X_2,X_3 \Big\rangle \Big|,X_5,X_6 \Big\| \int ,
\end{aligned}
$$

$$
\begin{aligned}
F_{19}\int \Big\| F_{18}\Big| F_7\Big\langle & F_6\Big\{ F_5\Big[F_4\{F_1[X_1,X_2],X_2,X_3\},F_3\{F_2[F_1(X_1,X_2),X_4],X_2,X_3\},X_4 \Big],\\
& F_3\Big[F_2[F_1(X_1,X_2),X_4],X_2,X_3 \Big],X_2 \Big\},F_3\Big\{ F_2[F_1(X_1,X_2),X_4],X_2,X_3 \Big\},X_4 \Big\rangle,\\
& F_5\Big\langle F_4\{F_1[X_1,X_2],X_2,X_3\},F_3\{F_2[F_1(X_1,X_2),X_4],X_2,X_3\},X_4 \Big\rangle,\\
& F_3\Big\langle F_2[F_1(X_1,X_2),X_4],X_2,X_3 \Big\rangle \Big|,X_5,X_9 \Big\| \int ,
\end{aligned}
$$

$$
\begin{aligned}
F_{17}\int \Big\| F_{13}\Big| & F_{12}\Big\langle F_{11}\Big\{ F_7\Big[F_6\Big(F_5\{F_4[F_1(X_1,X_2),X_2,X_3],F_3[F_2(F_1<X_1,X_2>,X_4),X_2,X_3],X_4\},\\
& F_3\{F_2[F_1(X_1,X_2),X_4],X_2,X_3\},X_2 \Big),F_3\Big(F_2[F_1(X_1,X_2),X_4],X_2,X_3 \Big),X_4 \Big],\\
& F_3\Big[F_2[F_1(X_1,X_2),X_4],X_2,X_3 \Big] \Big\},F_{10}\Big\{ F_3\{F_2[F_1(X_1,X_2),X_4],X_2,X_3\},X_8 \Big\},X_7 \Big\rangle,\\
& F_{10}\Big\langle F_3\{F_2[F_1(X_1,X_2),X_4],X_2,X_3\},X_8 \Big\rangle,F_9\Big\langle F_3\{F_2[F_1(X_1,X_2),X_4],X_2,X_3\},X_9 \Big\rangle,\\
& F_7\Big\langle F_6\Big(F_5\{F_4[F_1(X_1,X_2),X_2,X_3],F_3[F_2(F_1<X_1,X_2>,X_4),X_2,X_3],X_4\},\\
& F_3\{F_2[F_1(X_1,X_2),X_4],X_2,X_3\},X_2 \Big),F_3\Big(F_2[F_1(X_1,X_2),X_4],X_2,X_3 \Big),X_4 \Big\rangle \Big|,\\
& F_{10}\Big| F_3\{F_2[F_1(X_1,X_2),X_4],X_2,X_3\},X_8 \Big|,F_9\Big| F_3\{F_2[F_1(X_1,X_2),X_4],X_2,X_3\},X_9 \Big|,X_{11} \Big\|\int,
\end{aligned}
$$

$$
\begin{aligned}
F_{16}\int F_{15}\Big\| & F_{14}\Big| F_{12}\Big\langle F_{11}\Big\{ F_7\Big[F_6\Big(F_5\{F_4[F_1(X_1,X_2),X_2,X_3],F_3[F_2(F_1<X_1,X_2>,X_4),X_2,X_3],\\
& X_4\},F_3\{F_2[F_1(X_1,X_2),X_4],X_2,X_3\},X_2 \Big),F_3\Big(F_2[F_1(X_1,X_2),X_4],X_2,X_3 \Big),X_4 \Big],\\
& F_3\Big[F_2[F_1(X_1,X_2),X_4],X_2,X_3 \Big] \Big\},F_{10}\Big\{ F_3\{F_2[F_1(X_1,X_2),X_4],X_2,X_3\},X_8 \Big\},X_7 \Big\rangle,\\
& F_3\Big\langle F_2[F_1(X_1,X_2),X_4],X_2,X_3 \Big\rangle,X_4,X_{10} \Big|,\\
& F_7\Big| F_6\Big(F_5\{F_4[F_1(X_1,X_2),X_2,X_3],F_3[F_2(F_1<X_1,X_2>,X_4),X_2,X_3],X_4\},\\
& F_3\{F_2[F_1(X_1,X_2),X_4],X_2,X_3\},X_2 \Big),F_3\{F_2[F_1(X_1,X_2),X_4],X_2,X_3\},X_4 \Big|,X_5 \Big\|,\\
& F_{10}\Big\| F_3\{F_2[F_1(X_1,X_2),X_4],X_2,X_3\},X_8 \Big\|,F_9\Big\| F_3\{F_2[F_1(X_1,X_2),X_4],X_2,X_3\},X_9 \Big\|\int\oint
\end{aligned}
$$

As can be seen, this single but long equation, which is representing the reduced form for the system model, has four main components, i.e., F_{20} (.), F_{19} (.), F_{17}(.), and F_{16}(.). Each of these components is based on the following general structure built using 12 different symbols for brackets:

$$
\oint.....\int\ .....\Big\|.....\Big|.....\Big\langle\ .....\Big\{\ .....\Big[\ .....\Big(\ .....\{....[.....(...<.....>...)....].....\}....\ \Big).....\ \Big]...\ \Big\}...\ \Big\rangle....\ \Big|.....\ \Big\|.....\int\ .....\oint
$$